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Do You Know 551

Articles

THE MEADOW BROOK SEMINARS ON HIGHER LEARNING
Thomas H. Hamilton and Durward B. Varner 553

A SURVEY OF CURRENT CHANGES THAT ARE MODERNIZING ENGINEERING EDUCATION — L. E. Grinter 559

ENGINEERING EDUCATION AS IT AFFECTS UNITY IN THE PROFESSION — Frederick C. Lindvall 573

A PHILOSOPHY OF ENGINEERING EDUCATION — J. Stuart Johnson 580

CARNEGIE INSTITUTE OF TECHNOLOGY 588

THE WISCONSIN COURSE IN TRANSPORT PHENOMENA — Warren E. Stewart 593

HIGH LEVEL ENERGY TRANSFER PROCESSES IN MINING ENGINEERING — George B. Clark 600

PROFICIENCY OR PANIC? — Milton Alpern 606

A SOCIAL SCIENCE-HUMANISTIC COURSE WITH A PRACTICAL FOCUS: ENGINEERING ETHICS — Richard Conrad 609

UNDERSTANDING THE ENGINEERING WRITER — P. M. Zall 615

A COURSE IN THE HISTORY OF ENGINEERING — J. S. Dobrovolny 618

DEFINITION OF ENGINEERING 624

ECPD ACCREDITATION 625

THE PRINCIPLES AND PRACTICES OF COLLEGE RECRUITING 629

Teaching Positions Available 622

Candid Comments

FOREIGN LANGUAGES IN THE HUMANITIES PROGRAM — Knight Pryor 632

REDUCTION OF PHYSICS CONTENT IN THE ENGINEERING PROGRAM?
Elliot H. Weinberg 634

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Society Activities

ABSTRACT OF THE MINUTES OF THE MEETING OF THE EXECUTIVE BOARD AND GENERAL COUNCIL, NOVEMBER 13 AND 14 636

NEW MEMBERS OF ASEE 639

INDIVIDUAL MEMBERSHIP APPLICATION FORM 644

Notes

ASEE AT NUCLEAR CONGRESS 572

ELECTRONIC CONTROLS AND TRAFFIC SAFETY 579

RENSSELAER, AEC TO BUILD LINEAR ACCELERATOR 587

INTERNATIONAL ELECTROCHEMICAL VOCABULARY 2ND EDITION 599

UNIVERSITY OF WASHINGTON NUCLEAR CENTER 605

COLLEGE PHYSICS IS TAUGHT ON COAST-TO-COAST TV NETWORK 608

CONSTRUCTION EQUIPMENT DISTRIBUTION CURRICULUM AT CLARKSON TECH 614

UNITED ENGINEERING TRUSTEES 617

EDUCATIONAL REACTORS 623

JUNIOR ENGINEERS AT MONTANA STATE 624

34 FELLOWSHIP AWARDS ANNOUNCED BY NATIONAL SCIENCE FOUNDATION 628

UNION COLLEGE RECEIVES COBALT 60 GIFT 628

NEW GRADUATE STUDY PROGRAMS AT MICHIGAN 633

INSTITUTE OF SPACE SCIENCES AT CINCINNATI U. 638

AT THE ANNUAL MEETING IN PITTSBURGH 643

NEW ENGINEERING BUILDING FOR MIAMI OF FLORIDA

Modern laboratories, computing rooms and classrooms will be available September 1959 for students in the University of Miami School of Engineering when the J. Neville McArthur Building is scheduled for completion. Donor for whom the building is named is a pioneer Florida dairyman, civic leader and UM trustee. Ground was broken November 13, 1958 on the million dollar building located on the main UM campus. Twelve laboratories and dozens of classrooms and offices will be housed in the school's five-story center section and two two-story wings.

DO YOU KNOW . . . .

► . . . . That the individual membership efforts have bogged down and that the "bang up" year indicated in November is not materializing? Let's give the YETs a helping hand and end the year in a blaze of glory. A membership application blank is on page 644; tear it out and have a colleague fill it out now. Remember, he doesn't need to be an engineer and that we have English, Economics, and Humanistic-Social Divisions. The English Division is conducting a drive, so give it a lift if you can.

► . . . . The efforts of the Industrial Membership Committee have been going ahead full speed. The new brochure is a dandy. Copies have gone to all deans of engineering and to individuals in over 800 companies. If you want copies for distribution to your friends, write to the Office of the Secretary. The number of new members since last June is 25.

► . . . . That the Danmarks Ingeniorakademi, Bygningsfdelinger of Copenhagen has just been accepted for affiliate membership in the Society? Last spring the South African Iron and Steel Industrial Corporation, Ltd. was accepted as an industrial member. For many years Canadian schools have been members of the Society, but the two members listed above are the first overseas and not in U. S. possessions.

► . . . . That the Guidance Committee of ECPD has been making a pilot study of "boy's motivation to study engineering"? Twenty-six colleges were asked to participate in the use of a simple, six-point questionnaire for freshmen. Preliminary study indicates that counselors influence less than 6% whereas the family affects the choice of about 27%. The committee heretofore has not aimed any of its efforts at the PTA and is wondering if its thinking must be changed—or, since the counselors have so little influence must they be worked on? ECPD also is going to print Dean Emeritus N. W. Dougherty's book "Notes on Professionalism." "Your First Five Years" is the new title of ECPD's brochure aimed at the young engineer instead of management.

► . . . . That a newsletter entitled "The Superior Student" is regularly published by the Inter-university Committee on Superior Students? It is published monthly during the academic year by the University of Colorado on behalf of the committee at Hellens 112, University of Colorado. Since ASEE periodically receives inquiries regarding honors programs in engineering, it seems desirable that all members know of the existence of this committee and its newsletter.

► . . . . That the Rockefeller Brothers Report on Education, "The Pursuit of Excellence," in its discussion on "Excellence in a Democracy" makes the following comments about the superior students: 'It is now widely recognized that our society has given too little attention to the individual of unusual talent or potentialities. To make such an assertion is not to deplore the unprecedented time and money we have devoted to raising the general level of achievement. It would serve no purpose to replace our neglect of the gifted by neglect of everyone else. . . . It has not always been easy for Americans to think clearly about excellence. At the heart of the matter is a seeming paradox in democracy as we know it. On the one hand, ours is the form of society which says win," and rewards winners regardless most convincingly, "Let the best man

of origin. On the other, it is the form of society which gives those who do not come out on top the widest latitude in rewriting the rules of the contest. . . . Every democracy *must* encourage high individual performance. If it does not, it closes itself off from the mainsprings of its dynamism and talent and imagination, and the traditional democratic invitation to the individual to realize his full potentialities becomes meaningless. . . . The eighteenth-century philosophers who made equality a central term in our political vocabularly never meant to imply that men are equal in all respects. . . . The fundamental view is that in the final matters of human existence all men are equally worthy of our care and concern. Further, we believe that men should be equal in enjoyment of certain familiar legal, civil and political rights. They should, as the phrase goes, be equal before the law. . . . But men are unequal in their native capacities and their motivations, and therefore in their attainments. In elaborating our national views of equality, the most widely accepted means of dealing with this problem has been to *emphasize equality of opportunity.* The great advantage of the conception of equality of opportunity is that it candidly recognizes difference in endowment and motivation and accepts the certainty of differences in achievement. . . . We must not make the mistake of adopting a narrow or constricting view of excellence. *Our conception of excellence must embrace many kinds of achievement of many levels.* There is no single scale or simple set of categories in terms of which to measure excellence. There is excellence in abstract intellectual activity, in art, in music, in managerial activities, in craftmanship, in human relations, in technical work. . . . We must not assume that native capacity is the sole ingredient in superior performance. Excellence, as we shall later have occasion to note, is a product of ability and motivation and character. And the more one observes high performance in the dust and heat of daily life, the more one is likely to be impressed with the contribution made by the latter two ingredients. . . . We must recognize that judgments of differences in talent are not judgments of differences in human worth. . . . To sum up, it is possible for us to cultivate the ideal of excellence while retaining the moral values of equality. Whether we shall succeed in doing so is perhaps the fundamental issue in the development of our human resources. A challenge must be recognized before it can be met. Our society will have passed an important milestone of maturity when those who are the most enthusiastic proponents of a democratic way of life are also the most vigorous proponents of excellence.'

► . . . . That the President's Committee on Scientists and Engineers was dissolved on December 31? Consequently there will be no further issues of its newsletter entitled "News Round Up." Some of the functions of the committee are being taken over by the Office of Civil and Defense Mobilization, and copies of the final report will be distributed by that office. One of the final efforts of the committee is the publication of the book "The Scientific Revolution: Challenge and Promise," to be published by the Public Affairs Press, 419 New Jersey Avenue, S.E., Washington, D. C. The cost is $4.50 per copy. Leading educators, business men, and journalists have joined scientists in seeking to define the short and long range implications of the impact of science on 20th century America.

W. LEIGHTON COLLINS
Secretary

THE MEADOW BROOK SEMINARS ON HIGHER LEARNING

Sponsored by Michigan State University—Oakland

A synthesis and summary prepared by THOMAS H. HAMILTON and DURWARD B. VARNER, Vice Presidents, Michigan State University, with an introduction by J. D. Ryder, Dean of the College of Engineering.

On January 3, 1957, Michigan State University received from Mr. and Mrs. Alfred G. Wilson a gift of their 1400 acre Meadow Brook estate in Oakland County, Michigan, and two million dollars, for the establishment of a new university. The estate includes Meadow Brook Hall, one of the world's fine residences, and its art collection, and is located in a rapidly growing population area three miles east of Pontiac and twenty-five miles north of the center of Detroit.

The building of a new educational institution is a very rare event in the academic world, an event which offers opportunities in educational experimentation, in breaking of purely traditional bounds, and in planning for education for tomorrow's world which should not be approached with any but the most open-minded view. To this end, Michigan State University officials, aided by an enthusiastic group of civic leaders of the Oakland-Macomb county (Michigan) area, called upon some of the educational leaders of the United States to aid in giving direction to the program to be conducted at this new university.

In carrying out this philosophy, seminars of invited authorities have been held covering engineering, teacher education, business, and science and liberal arts. The paper which follows is a summary of the ideas advanced by six engineering educators at a Seminar on Engineering Education conducted at Meadow Brook Hall on the estate on August 16, 1958. The panel members were:

Dr. Eric A. Walker, President, Pennsylvania State University
Dr. C. Richard Soderberg, Dean of Engineering, Massachusetts Institute of Technology
Dr. Lee A. DuBridge, President, California Institute of Technology
Dr. Newman Hall, Professor and Chairman of Mechanical Engineering, Yale University
Dr. Frederick E. Terman, Dean of Engineering, Stanford University
Dr. John D. Ryder, Dean of Engineering, Michigan State University

In prior internal discussions Michigan State University had recognized the present-day trends looking toward further science content in engineering education. With this in mind, but seeking an otherwise open-minded approach, Michigan State University asked these gentlemen the following question:

> "With your knowledge and experience in the field of engineering education, how would you organize a program in engineering science at this new institution to train engineers for the half century ahead of us?"

The following is a summary of the ideas that came from the discussions that resulted.

Throughout the land there seems to exist a considerable and probably healthy dissatisfaction with the present state of engineering education. This dissatisfaction is shared, to some degree, by all who are concerned with the enterprise of engineering education. It exists among its purveyors (the faculties), the consumers (the students) and the users of the ultimate product (industry and government).

Thoughtful and balanced men who give attention to this problem recognize clearly that there is no basis for assuming that this dissatisfaction stems either from the inadequacy of performance of our engineering schools in earlier days, nor for that matter even the nature of their activities at the present. Taken in the large, the record of our engineering schools has been remarkably good. But in a sense we have come to realize that certain characteristics of our immediate national and international future have now become known, and in the minds of those who recognize the direction in which we move it becomes clearer that while much of what is now being done in engineering education must continue, there need to be added new dimensions if the challenge of that future is to be met with succesSs.

Basically the problem that bedevils the engineering educator stems from the change in the nature of our society. Two phases of this change cause us to recognize the inadequacy of what now is being done. One of these involves the sheer size of the work with which the engineer must now attempt to cope. At the turn of the century the engineer was said to be assigned to "jobs," and these were in effect small affairs for the most part relatively easily managed and unencumbered by the complexities which emerge from enormity. But in 1958, the engineer finds himself assigned not to a job but a "project." [1] The "project" rather than being small and simple, typically will be characterized as very large and extremely complicated. The year 1900 could not even envision the kinds of engineering problems which it has already been necessary to solve in connection with such projects as the Dewline or the several guided missiles projects.

The second basic difference between 1900 and 1958, and these differences are by no means mutually exclusive, arises from the fact that these mid-twentieth century engineering undertakings require of the engineer a scope and range which were quite unnecessary for the engineer at the turn of the century. The engineer at the head of a multi-billion dollar project will find that he must have some knowledge of, and be able to communicate with, the practitioners of law, of finance, and of politics. Here, as many an engineer has learned to his considerable discomfort, blueprints and formulae prove unsatisfactory as media of communication. Thus it becomes clear that the engineer of the future must not only be infinitely more skilled in his own discipline, but he must be at least an adequate generalist in the disciplines related scientifically to his own as well as those liberal disciplines which permit him to understand something about the nature of the physical and social world and the human beings and their works with which that world is populated.

The truth of the matter is that we shall not be able to develop in any one individual the capacities to do all of the kinds of work which will be demanded in the total engineering process of the future. We are faced with the necessity of training not one but

[1] It is recognized that in some quarters the term "project" has a bad odor, but here it will suffice to demonstrate the distinction in mind.

three types of engineering practitioners. Two of these types of educational programs we either now have or at least have planned. It is to the third area that an engineering school starting from the present and planning for the future should devote its attention.

Briefly put, the three kinds of engineering practitioners which will be needed can perhaps be described as the innovators and directors, the applicators, and the technicians. Most of our present engineering schools are doing an adequate job of educating the middle group. These are the engineers who will take the ideas of others and design the machinery for implementation. Even these, however, will probably have to deal with applications involving much more sophisticated situations than have been customary in the past. At the lower level of the technician, it is probable that we are not as yet completely tooled up educationally to produce these in the required abundance. But the plans that are common in many states to develop technical institutes in connection with community and junior colleges would seem to give promise that this problem is on its way to a solution.

Innovators

It is education for the innovating and directing engineer of which we are now in such very short supply. Those few innovating engineers we now have seem to have risen to their position in spite of the frustrations of educational programs designed essentially to make applicators of them. One of the most remarkable things about genius is that it seems almost impossible for even a bad education to frustrate it.

On one matter there seems to be rather clear agreement and this is that there are relatively few individuals equipped with the intellectual ability, the willingness to work, and the perseverance necessary to be educationally inducted into the innovating class. Here, perhaps, we come to our first principle, and this is that any institution which intends to devote itself either wholly or partially to the education of the innovating and directing engineer must restrict the students undertaking such a program to those of high intellectual ability who are possessed of a willingness to work and presevere. Just how high this intellectual ability must be is, of course, not known with any precision. Whether it is a program that can be undertaken only by the top 2 per cent or by the top 10 is a matter on which wisdom will only grow from experience.

It is equally clear that the able students destined to undertake the kind of program here envisioned should be identified as early as possible, and from the moment of identification given special programs commensurate with their ability and designed to lead them in the desirable direction. Again there is no evidence that any man has been able to prescribe exactly the moment at which definitive identification and subsequent curricular segregation is possible. There seems to be agreement that this should take place at the very latest by the end of the sophomore year in the university, and imagination may develop ways of moving the date closer to the end of the secondary school experience.

If it be accepted that the most important role which a new and unsullied engineering school might undertake is the education of these innovators and directors, then, of course, the logical first question is of what should this education consist? Short of experience as we are, it is easier to demonstrate what an education such as is here under discussion should not contain. Certainly this program should eschew any of the emphasis on voca-

tionalism which has characterized too many engineering programs. This is probably true for all of engineering education, but it is particularly applicable in the present instance. The reasons for this are clear and simple once analysis is applied. To try to teach narrow technologies on the university campus is but to dabble in certain obsolescence. The rate of change within industry is such that inevitably the special vocational skills learned on a campus will be out of date by the time the student is in a position to apply them in practice. In view of this, industry has come to recognize that the problem of teaching the application, the art, is its province and not the university's. This is a kind of teaching that industry is much better prepared to undertake.

To state positively, however, of what the new curriculum should consist is more difficult. Perhaps the term "engineering science" best connotes what is here in mind even though the engineering profession has not as yet succeeded in spelling out in any sort of a definitive fashion all that is here involved. Certainly it means concern with basic principles as opposed to knowledge of the art of application.

A great deal of the difficulty in defining more clearly engineering science arises from the fact that it seems not to fit comfortably either of the two categories into which it is quite common to divide science. While all who have given more than the most superficial of consideration to the classification are convinced of its inadequacy, the fact remains that we tend to divide science into the pure and the applied. Pure science can be roughly defined as that kind of scientific endeavor the sole purpose of which is to understand phenomena. Applied science, on the other hand, is interested in securing scientific information in order that it may be applied to utilitarian objectives.[2] The best thinking now would seem to indicate that engineering science is neither of these, some of both, and possibly something in addition. Beyond a recognition that engineering science must emphasize first principles of science and pay relatively little attention to the art of application in particular situations, there is little agreement on its precise content.

Certainly the leaders in the field of engineering education are agreed that in addition to replacing present courses in engineering with experiences in the engineering sciences, there must also be given a great deal more attention to those disciplines which undergird and buttress engineering. Particularly is this true of the natural sciences and mathematics. The engineering innovator of the future will have to be far better educated in physics and in chemistry and particularly in mathematics than has been true in the past. This is the case not only because his success as an engineering scientist will depend on his capacity to use these tools, but also to give him one aspect of the greater range and scope which was mentioned earlier.

A third phase of the education of the innovating engineer to which attention must be given is that which might be called liberal or general or social-humanistic. This is of prime importance to him professionally, for as has been suggested above, the type of engineer here being contemplated will have to be able to understand and communicate successfully with men in many other professions and vocations if he is to successfuly perform his task. Nor would it be wise to overlook the fact that the student will become a

[2] The difficulty with this classification of pure and applied science is that basically it depends on a knowledge of the subjective motivations of the scientist, the nature of which he may be unaware of himself.

man and a citizen before he becomes an engineer, and his education as man and citizen should no more be neglected than his education as an engineer.

There remains, of course, the problem for one who would construct a program for the engineering scientist as to how much of the time should be devoted to these three phases of the total. Those schools which seem to have most closely approximated the curriculum here under discussion, devote approximately 20 per cent of the student's time to the liberal, 35 per cent to the scientific and mathematical, and 45 per cent to engineering science. Some would contend that 40 per cent of the time for engineering science and 30 per cent for both the physical sciences and mathematics and liberal and general education would give greater promise of achieving the objectives in mind.

Questions have been raised as to whether it is possible, even with the brightest of students and the best of faculties, to achieve this three-faceted objective within four years. Some institutions have contended that it is not, and, as a result, have inaugurated five-year programs in the field of engineering. The consensus of opinion seems to be that this is not wise. Frequently extending to five years has simply meant a dilution of the program and the introduction of matters better left untaught. A wiser solution seems to be to recognize, first, as should be recognized with all undergraduate programs, that it is simply impossible in four years to teach everything that might be desirable, and, secondly, to recognize that for the engineers here under consideration some graduate work would seem almost essential with most of these engineering scientists continuing on to the level of the doctorate.

It already has been emphasized that a program in engineering science cannot possibly be undertaken by all of the students who elect to become engineers, but rather that it is a program which should be reserved only for the most able and the most diligent. But it is equally true that such a program can by no means be taught by all engineering faculties. Such a program as is now under discussion will require a faculty of the very highest quality—the members of which themselves approximate at least some of the excellences desired in the students. This means that an institution undertaking such a program must provide salaries which will permit it to compete for the very ablest of engineering teachers. But this is not the whole, perhaps not even the heart, of the matter. Research opportunities and the chance to work with graduate students will weigh equally heavily with good engineering scholars as a means of inducement. While it is recognized that any new institution will have to concentrate its early attention on instruction, if engineering science is to be the motif, then from the beginning there must be envisioned both a graduate program and opportunities for research.

To some extent, an institution located in an area where many fine engineers are employed could rely on the services of some of these engineers on a part-time basis, if they are used to teach the areas in which they have great competence and not to compensate for a shortage of permanent staff. But there is no substitute for a core of full-time, permanent faculty members whose exclusive responsibility is the preservation, discovery, and transmission of knowledge of and about engineering science. It seems likely that the kinds of faculty members who would be most attracted to a new venture of this sort would be the extremely able young teachers and

scholars who saw in the venture an opportunity to make a significant contribution to the development of engineering scientists.

The approach which has here been taken, it must be emphasized, is only partial. It would be wrong to suggest that all schools of engineering should so concentrate their efforts, for not only has it been pointed out that only a few can qualify intellectually for this kind of program, but, moreover, the future will still be characterized by great needs for the other two types of engineering practitioners earlier described. These, too, must be appropriately educated and trained.

It is true that the development of this kind of an engineering science curriculum poses problems for a state university. In the first place, it demands a degree of selectivity for the engineering curriculum which is sometimes not characteristic of a public university; but perhaps the time has come when the public is willing to recognize that while it must provide higher educational opportunities for great masses of students, it also, if the public is to remain healthy, must provide special kinds of opportunities for the unusually able.

It seems doubtful that an institution which considered itself only regional in terms of a service area could well embark on this curriculum, for in order to procure a sufficient number of talented students only an entire state or a region of several states or indeed the nation provides an adequate reservoir of student talent.

One would speculate with a new institution as to what kind of an organization should be contemplated. Those of long experience in existing institutions are aware of how often the division of the university into colleges, and subsequently into departments, stands in the way of the integration of disciplines which now seems so necessary to educational progress. No one has really examined the possibility of operating a university without either college or departmental organizations whether they be under these names or not. And it is a matter to which thought should be given. Perhaps by the very nature of a social institution some functional organization is necessary, but certainly it would be well when developing a new institution to avoid the rigidity and intellectual provincialism which unfortunately characterizes the present organization of too many institutions of higher learning. In engineering, for example, there might be some merit in refusing to impose the current departmental organizational pattern on a new school and, instead, organizing both the curriculum and the administration of the school around such concepts as materials, energy, and man.

One hundred years ago engineers invented things that scientists did not understand. The steam engine, far from being based on previously completely known scientific principles, raised questions which subsequently the scientists had to answer. Today the situation is reversed. Invention and innovation will be the product only of those who are firmly grounded in the sciences. Beyond the level of the gadget, the bright intuitionist with a mechanical bent will make few major contributions in the century ahead. We must depend for our engineering progress on extremely able men who are well educated liberally, scientifically, mathematically, and as engineering scientists.

A SURVEY OF CURRENT CHANGES THAT ARE MODERNIZING ENGINEERING EDUCATION

L. E. GRINTER

Past President ASEE, Dean of the Graduate School, University of Florida, Gainesville

When the writer was asked to summarize for the Council of ASEE the changes in engineering education that had taken place since the presentation of the *Report on Evaluation of Engineering Education* in 1954–55, he quickly concluded that facts rather than opinion would be needed. One senses that engineering education has been passing through a period of accelerated evolution in which the *Evaluation Report* was only one inciting factor. Others were the economic boom which was sustained by creative activities of engineers, the introduction into the engineering field of scientific advances at a rate greatly accelerated by governmental and industrial emphasis upon applied research, and the intensive technological competition from abroad. These extraordinary factors would have brought about a change in engineering education without the aid of ASEE. However, its timely report, which presaged these influences and suggested the direction for curricular change, doubtless accelerated normal adjustments.

Publications and Reports

The office of ASEE furnished a list of journal publications judged to relate to the work of the Committee on Evaluation of Engineering Education. It was found that 24 such articles appeared in 1953–54, that 11 appeared in 1954–55 and that 12 were published in 1955–56. Only 6 articles related to curriculum revision appeared in 1956–57, but the number has risen to 18 through the April issue of the JOURNAL for 1957–58. It appears then that curricular adjustment is again a matter of increased concern. This may well be due to the stimulation of the past year produced by our realization that international competition will greatly influence the work of engineers over the next decade. It is also doubtless influenced by pressures for more engineers trained with the theoretical tools needed for active functioning with research teams.

To obtain facts regarding the extent of adjustments in curricula and in the faculties that teach engineers, the writer contacted all deans of engineering and received useful data from more than fifty per cent of our engineering colleges. Since the *Report on Evaluation of Engineering Education* had been circulated in two preliminary forms in 1953 and 1954 before its final publication in 1955, it seemed desirable to permit the institutions to choose any date after 1953 as a base from which to report changes and adjustments. Generally speaking, a period of about four years was involved. As the reports were studied it became evident that there were some noticeable variations related to basic objectives of the institutions reporting. Hence a subdivision of institutions based upon a classification suggested by S. C. Hollister, "Analysis of Educational Potential in Engineering Colleges," JOURNAL, April, 1958, pp. 586–593, was adopted. All institutions that awarded Ph.D. degrees in engineering in 1952–55, of which forty-five had reported, were placed in group 1. All

TABLE I

ENGINEERING FACULTY CHANGES 1954–58

Characteristics of the Engineering Colleges Reporting	Increase of Faculty Reported Numerically			Increase of Faculty Reported as a Percentage			Salary Increase of Faculty Reported as a Percentage			Per Cent Reporting an Increase in Ph.D.'s on Faculty	Per Cent Reporting an Increase in M.S. Degrees on Faculty	Per Cent Reporting an Increase in Faculty Research Interest	Average Number of Present Vacancies per Institution
	Max.	Min.	Avg.	Max.	Min.	Avg.	Max.	Min.	Avg.				
Colleges that awarded Ph.D. degrees in 1952–55 (45 reporting)	62 (33 reporting)	1	25.4	40% (9 reporting)	3%	25%	80% (40 reporting)	5%	29%	80%	42%	58%	6.1
Colleges that awarded Master's degrees in 1954–55 (35 reporting)	68 (21 reporting)	4	16.8	50% (9 reporting)	10%	36%	150% (33 reporting)	10%	39%	80%	51%	60%	3.4
Colleges that awarded only first degrees in engineering in 1954–55 (26 reporting)	39 (16 reporting)	1	11.2	94% (7 reporting)	12%	34%	70% (25 reporting)	10%	34%	54%	50%	38%	3.9

TABLE II

CHANGES IN SCIENCE CONTENT OF ENGINEERING CURRICULA

Characteristics of the Engineering Colleges Reporting	Changes Reported in Mathematics Content				Changes in Chemistry		Changes in Physics Science Content		
	Diff. Equations Added for All Engineers	Diff. Equations Added for Some Engineers	Required Mathematics Strengthened	Required Mathematics Under Study	Chemistry Strengthened in Credit or Content	Chemistry Requirement Under Study	Required Physics Credit Increased	Physics Requirement Under Study	Science Content Added in One Area
Colleges that awarded Ph.D. degrees in 1952–55 (45 reporting)	8%	26%	49%	18%	11%	16%	40%	20%	134%
Colleges that awarded Master's degrees in 1954–55 (35 reporting)	11%	28%	34%	6%	11%	11%	37%	9%	121%
Colleges that awarded only first degrees in engineering in 1954–55 (26 reporting)	4%	19%	54%	15%	12%	4%	35%	4%	123%

institutions that awarded engineering master's degrees in 1954–55 but not Ph.D.'s were placed in group 2. Thirty-five institutions fitted into this category. The remaining twenty-six institutions, which had awarded only the bachelor's degree in engineering in 1954–55, were placed in group 3. These groups are separated vertically and are indicated in the left-hand columns of Tables I, II, and III.

Growth and Strength of Faculties

It is to be noted in Table I that all institutional faculty groups have grown in size. Those faculties granting the Ph.D. degree, for example, have increased on the average by twenty-five faculty members, which, incidentally, represents about a twenty-five per cent growth. This growth in a large majority of institutions has been accompanied by an increase in the number of Ph.D.'s on the faculty and also by an increase in master's degrees. Accompanying this increase in scholarly attainment there is reported a strong growth in faculty interest in research. There is nothing here to raise a question as to the possible weakening of engineering faculties through industrial or other competition. In fact, the reverse seems indicated although a study of actual percentages of Ph.D.'s on engineering faculties by years might produce a somewhat different conclusion.

Doubtless it is significant that salary increases reported in Table I have averaged seven per cent per year for the most advanced institutions and ten per cent per year for the middle group. Apparently the group awarding the Ph.D. degree had sufficiently high salaries in 1954 to remain competitive with somewhat smaller percentage increases in salaries than those not awarding the doctor's degree. The fact that all engineering institutions taken as a group appear to have increased salaries about 8.5 per cent per year is a strong indication that forces are evolving which will provide a one hundred per cent increase in engineering salaries needed by 1968–70 in order to generate faculties to meet the radically increased demands in undergraduate education, graduate education, and fundamental as well as applied research that are just becoming evident in 1958.

Curricular Changes in Science

Table II summarizes the curricula changes that have influenced the science content of engineering education. In mathematics it is clear from the reports that significant changes have already occurred. Even though differential equations was a reasonably common requirement for many engineering curricula in 1954, an additional eight per cent of institutions have made it a universal requirement for engineers and about twenty-five per cent of the engineering schools have added it as a requirement in one or more curricula. Nearly one-half of the colleges of engineering report a strengthening of the mathematics requirement in some manner. These devices may include increased credit hours, increased entrance requirements, or merely an accelerated pace. They are clearly stimulated by the belief that a deeper knowledge of mathematics lies at the heart of the engineer's problem of maintaining leadership in the world of nucleonics, astrophysics, automatic computation, rocketry, solid state metallurgy and systems analysis that will soon make possible such advanced devices as space platforms and anti-missile missiles.

In chemistry the curricular adjustments are less pronounced than in mathematics, but still eleven per cent of institutions report a strengthening of chemistry credit or content. An equal number have the chemistry se-

TABLE III
ENGINEERING CURRICULAR CHANGES OTHER THAN SCIENCE

Characteristics of the Engineering Colleges Reporting	Changes Reported in Engineering Courses of All Types						Humanistic and Social Science Sequence
	Required or Elective Courses in Engineering Science Increased	Required Courses Revised to Increase Content of Engineering Science	Engineering Analysis and Design Strengthened	Engineering Science, Analysis or Design Strengthened (Total of 3 previous columns)	Courses in Engineering Practice or Art or Other Technical Courses Including ROTC Reduced or Eliminated	Engineering Curricula Now Under Study	Required Credit Increased or Electives Provided
Colleges that awarded Ph.D. degrees in 1952–55 (45 reporting)	40%	29%	18%	87%	87%	58%	60%
Colleges that awarded Master's degrees in 1954–55 (35 reporting)	20%	31%	17%	69%	83%	54%	66%
Colleges that awarded only first degrees in engineering in 1954–55 (26 reporting)	12%	23%	19%	54%	65%	46%	58%

quence under present study. Since 1954, from thirty-five to forty per cent of engineering schools have increased the credit hours devoted to the study of physics. Frequently the change involved has been rather drastic in terms of an added year of study of physics with the introductory course starting earlier than the sophomore year. In other cases the introductory course remains in the sophomore year but is followed by a required course in nuclear or modern physics in the junior or senior year. When one sums the percentages of institutions reporting curricular additions either in mathematics, physics, or chemistry the result exceeds 100 per cent, which signifies that credit hours have been added on the average in more than one area of science.

Curricular Changes in Humanistic Courses

Perhaps it will be something of a surprise that some sixty per cent of institutions have found it possible in the past four years to increase the required or elective credit in the humanistic and social fields for engineers. At long last the recommendation of the 1945 ASEE Committee on Engineering Education after the War, reemphasized by the Committee on Evaluation of Engineering Education in 1955, that about one-fifth of engineering study should be in liberal fields, seems likely to be accomplished. Time has been gained by reduction or elimination of ROTC credit in some instances or by readjusting other technical studies as required. Curricula will contain fewer courses of technical non-engineering content and more courses of liberal content in the immediate future. There still seems to be a tendency to pre-select for the student the studies that he shall cover in the liberal field, although a reasonable percentage of institutions report a more liberal policy of permitting the student to exercise his initiative and develop his special interests through choice of coordinated humanistic and social electives.

Curricular Changes Involving Engineering Courses

Although changes in science and humanistic courses predominate, some eighty-seven per cent of institutions that grant the Ph.D. degree report the dropping of courses in engineering practice, art or other technical areas and the introduction of work in engineering science or analysis and design. Most of these changes were occasioned by the acceptance of the theory that the fields of engineering science are essential background for engineers and that the emphasis in these areas must be increased. In fact, forty per cent of the institutions granting the Ph.D. degree report an increase in required or elective study in the engineering science areas. Perhaps it is equally significant that despite these changes more than fifty per cent of the institutions report their undergraduate curricula to be under present study.

New Curricula in Engineering

It seemed significant in the replies received that a large percentage of new curricula or options mentioned were of a rather scientific nature. Such titles as Engineering Science, Engineering Physics, Engineering Mechanics, and Nuclear Engineering predominated. One new title, Mathematical Engineering, was noted although some additional curricula were described as being essentially of the same character without use of the name. The objective of such curricula or options seems to be to produce a person who can aid research engineers in solving difficult theoretical problems by use of pure and applied math-

ematics, statistics, and machine computations. It should be noted that no new undergraduate curriculum in nuclear engineering was reported although there was mention of several at the master's degree level. Mention was also made of nuclear emphasis or options in long established engineering departments as the preferred solution to this need by several institutions.

QUOTATIONS ON UNDERGRADUATE CURRICULAR CHANGES FROM LETTERS FROM DEANS

No set of quotations as brief as those which follow could give a well balanced viewpoint of reports received from more than one hundred institutions expressed through a thousand pages of written and duplicated material. Hence the writer has merely quoted those comments that briefly and succinctly clarify areas of curricular revision. It may be that these quotations overemphasize the degree of change that has occurred over the past few years, since those who reported may have tended to mention advances rather than static areas of the curriculum. However, considered in proper perspective along with the tabular material that precedes this section these quotations give vitality to the statistical picture of curricular revision. One senses in these comments an acceptance of rapid change as a normal expectancy in a world that lives in an era of scientific and technological eruption. There is also a feeling of assurance that change can be expected to continue to meet any challenge that may come to the engineering profession.

COMMENTS CONCERNING THE MATHEMATICS SEQUENCE
(from different institutions)

"In general, from three to six semester credit hours have been added in mathematics for all engineering curriculums."

"EE has added differential equations, advanced calculus, and two other mathematics courses under the EE label."

"The requirement of ordinary differential equations by all departments, and the inclusion of advanced differential equations as an elective has been made."

"In general practically all electives are now being used in the fields of mathematics and physics. It is not at all uncommon, especially in the area of mechanical engineering and electrical engineering, to have students graduate with two or more courses of advanced mathematics beyond ordinary differential equations. It is also very common to find one or two courses in physics beyond that normally required."

"Algebra and trigonometry have been eliminated as required freshman courses, and instruction in mathematics next fall will start with analytic geometry. The six semester hours thus gained will be used for a course in atomic physics and three semester hours of differential equations for all engineers."

"The entire mathematics sequence has been upgraded. We are modifying the course in engineering analysis to include some work in statistics."

"A first course in differential equations is completed at the end of the sophomore year."

"E.E. has added an additional four hours, making a total of 9 hours in an advanced mathematics sequence covering differential equations, LaPlace transform, Bessel functions and matrix algebra."

"We have increased the mathematics in most curricula by at least three hours."

"Our mathematics sequence now consists of three 5-hour courses in calculus and a 3-hour course in differential equations offered during the sophomore year."

"All engineering students now require not only differential and integral calculus but also differential equations. Electricals re-

quire an additional term of advanced mathematics in the junior year."

"A third year of mathematics at the advanced calculus level is being added to the departments of electrical, mechanical and petroleum engineering."

"Differential equations was made a requirement for all engineers."

"Differential equations is a requirement for graduation in all engineering curricula. This was made possible by requiring trigonometry as an absolute entrance requirement."

"The total credit hours in mathematics was increased from 18 to 21."

"During the last few years advanced calculus has been made a requirement in chemical engineering and civil engineering."

"While the required credit hours in mathematics have been cut the engineering student now starts his mathematics at a level of two courses higher and as a result takes an additional higher course in this subject than previously."

"Additional math has been incorporated in the aeronautical, chemical, civil, industrial, and metallurgical engineering curricula."

"Statistics will probably be offered to all students because our faculty believes that few experiments can be performed properly without the proper use of statistics."

"Civil, industrial, and mechanical engineering have each added a course in differential equations to their requirements at the expense of engineering courses."

"We start our engineering math with analytical geometry, two courses of calculus in the freshman year, followed by two courses of differential equations in the sophomore year, and a course in numerical analysis. Next year we are adding a course in the use of the digital and analog computer in each department. We are also offering in the chemical, civil, and electrical engineering departments a third or fourth year option-course in mathematics, especially adapted to the needs of that department."

COMMENTS CONCERNING THE PHYSICS SEQUENCE
(from different institutions)

"All engineering students take a physics sequence extending through two of our years for a total of 12.8 semester hours."

"The terminal course is atomic physics which was introduced in 1955 and is required of all engineering students."

"Course content of physics has been revised to include more modern physics."

"The 12 credits in physics have been rearranged to include atomic and nuclear physics."

"We have added atomic physics to the electrical engineering program."

"Civil engineering dropped 9 courses and added 9 courses. One of the latter was atomic physics."

"Physics (was changed) from two five-hour courses to three four-hour courses, including more modern physics."

"We are revising our physics (sequence). We had required two years but have added a course in modern physics."

"Two of these curricula also are including work in modern physics."

"To strengthen the engineering sciences, a course in modern physics for engineers was added."

"The physics stem ends with modern physics."

"There is at present much study on the possible advantages of offering a third semester of physics in the first term of junior year, especially for M.E., E.E., and Ch.E. students."

"Every student is required to take four semesters of physics in courses primarily for engineering students. This is twice the physics previously required."

"These new curricula are characterized by having four courses in physics in the freshman and sophomore years with strong emphasis on modern physics and a fourth course devoted entirely to atomic and nuclear physics."

"The required 3-hour course in electrical measurements given by the Physics Department will be dropped and a 3-hour course in modern (nuclear) physics, given by the Physics Department, is to be required."

"The addition of one semester of physics to all curricula (has been made)."

"Modern physics is now a much more popular elective than it was a few years back."

"All curricula have a course in nuclear physics, not formerly included."

"We also require more physics and chemistry than was previously required. The physics

requirement is equivalent to 15 semester units."

"Since 1954 we have changed the engineering problems of our common freshman (year) to an engineering concepts (course) which is essentially the subject matter of classical physics taught from an applied approach. This has made possible the elevation of subject matter in engineering physics, the increase of physics hours, and the teaching of physics by application of calculus."

"Modern physics will probably be required in addition to the three-semester sequence in classical physics."

"Credits assigned to basic physics courses were increased from 12 to 15."

COMMENTS CONCERNING THE CHEMISTRY SEQUENCE (from different institutions)

"We are initiating this fall an entirely new course given by the Chemistry Department on the structure of matter. This will replace the first course of the standard general chemistry curriculum. We will after this year have three required courses in chemistry for all engineers instead of two."

"Addition of physical chemistry to chemical engineering (accomplished in 1955 and to be continued)."

"Credits assigned to basic chemistry courses were increased from six to eight."

"We complete two years of mathematics, physics, and chemistry."

COMMENTS CONCERNING ENGINEERING SCIENCE (from different institutions)

"We believe that the future education for engineering in the university should be based on the engineering science concept, rather than on the traditional emphasis on art, technology, and skill."

"A new course emphasizing thermodynamic calculation has been substituted. All curricula have increased slightly the emphasis on basic sciences and have increased greatly the emphasis on the engineering sciences."

"In every course in the entire College of Engineering there has been a very strong trend towards a greater and greater reliance on the basic sciences. This in turn has greatly strengthened the content of the engineering sciences."

"There is greater emphasis on mathematics, basic science, and engineering science."

"As required courses, a fifth term of physics, modern physics, a course in physical chemistry, a senior course in chemical engineering, a course in statistics and a laboratory course in stress analysis. The course in thermodynamics has been changed to fit the needs of all departments rather than the needs of the Mechanical Engineering Department alone. All interested departments now take part in planning and teaching the course."

"Our mechanical engineering curriculum has similarly been completely over-hauled and reoriented this year, the majority of the courses being entirely new ones. Courses in power equipment, metal processing, kinematics, heat engineering, mechanical engineering laboratory, mechanical design, air conditioning and the like have been replaced by courses in mechanics, dynamics, thermodynamics as an engineering science, engineering properties of materials, mechanical engineering analysis, those covering the modern approach to fluid mechanics, heat transfer, advanced dynamics and vibration, power systems and the like."

"More stress on heat transfer in mechanical engineering and the transference of internal combustion engines to an elective status (has been made)."

"More stress (has been placed) on fluid dynamics in various departments."

"The elimination of the surveying requirement and the introduction of heat transfer and electronics as requirements for mechanical engineering (has been accomplished)."

"In mechanical engineering, more emphasis on heat transfer and heat (jet) propulsion (has been given)."

"All students take a course in physical metallurgy which includes physics of solids."

"Individual courses keep progressing in general toward a higher level of engineering science content."

" 'Engineering sciences' plus the engineering concepts (course) of the common freshman year will constitute the core pattern of each curriculum in engineering."

"Our Aeronautical Engineering Department has strongly modified its program by discarding courses on details of airplane design and substituting more unified treatments of aerodynamics, mechanics, and thermodynamics."

"The engineering sciences have been coordinated with all engineering curricula hav-

ing identical courses rather than specialized courses for the different groups."

"The new program has increased emphasis on the engineering sciences by revisions of existing courses and by introduction of additional courses."

"The trend in the College of Engineering over the past five years has been to reduce the laboratory and to increase the engineering science offerings."

"Several curricula have added fluid mechanics and heat transfer, vibrations, advanced strength of materials."

"Thermodynamics will probably be offered as the same course to all engineers for a 3-hour course and then will be followed by more specialized thermodynamics for the various curricula."

"A new required course in materials, based upon modern physics, is included."

"The six basic engineering sciences as defined in the ASEE report were incorporated into all degree curricula. The single exception at the present time is a course on rate processes for civil engineering students."

"Six courses in the engineering sciences, which are organized under an undergraduate group committee on Engineering Science with representatives from all five engineering schools (characterize this new curriculum)."

"The work in materials has become an introduction to the physics and chemistry of the solid state."

"Students now have better and more preparation in basic sciences and can progress more rapidly in the engineering sciences."

"The civil engineering program has been reorganized and several of the more applied courses have been dropped in favor of devoting more time to basic engineering science courses."

COMMENTS ON ENGINEERING ANALYSIS AND DESIGN (from different institutions)

"Courses that were formerly largely descriptive have given way to courses in engineering analysis and design."

"The engineering elective is a 6-hour course in analysis, synthesis and design."

"Although the course contents have been changed with greater emphasis on the mathematical approach to engineering analysis and design, there has been little change in the number of semester credit hours. However, the material covered has been increased in both scope and difficulty."

"We are slowly building toward more comprehensive senior year offerings in analysis and design."

"In general we have fewer required courses in the practice aspects of engineering and more analytical courses."

"All engineering courses at the junior and senior level have been changed. Some of these changes represent almost 100% revision of content and emphasis."

"An attempt (is being made) to change design to creative synthesis."

"Higher courses have been added to the curriculum such as introduction to nuclear engineering, servomechanisms, theory of automatic controls, fields and waves, modern materials properties, advanced strength of materials, mechanical vibrations and advanced fluid mechanics. Also thesis requirements have been added."

"A rigorous scientific approach has been taken in all engineering courses including technical drawing. The 'know-how' has been de-emphasized and the 'know-why' has been emphasized."

"Internally, the engineering courses are continually being revised, with more emphasis on true fundamentals and the elimination of training for specific professional skills."

"More emphasis has been placed on engineering analysis and design."

"Our 1958 curricula as compared with the 1953 version is basically marked by a considerable change from the 'how to do it' type of course to one more soundly based on mathematics and science."

"Civil engineering, industrial engineering, and civil engineering construction have made more drastic revisions than the other curricula. These have definitely been toward an engineering science and engineering analysis approach."

"Attention at this moment is on strengthening of design."

"Greater stress is being laid on design, which is being used as an integrating course for the fundamental sciences previously studied."

"We have for quite awhile been steering our course work away from application and to-

ward core material in basic science, engineering science, and engineering analysis and design."

COURSE ELIMINATIONS INVOLVED IN REORIENTATION
(reported by different institutions)

"ROTC is now an overload in the first two years and substitution for technical or humanities courses is no longer permitted."

"Removal of the alternation of the junior and senior humanities courses with the advanced ROTC courses (has been done)."

"There has been a significant reduction in descriptive technical courses and a marked decrease in the number of options."

"We have improved the stature of our course in engineering drawing while decreasing the amount of time devoted to the subject. We have done this by consolidating a two semester drawing sequence into a one semester full course load."

"There has been a decrease in emphasis on application courses."

"A full term course in industrial chemistry has been dropped."

"The shop and surveying courses have been eliminated. The former drawing courses have been reduced to one, three credit course, and this emphasizes pictorial representation."

"The required course in steam and gas engines was replaced by a course in applied thermodynamics."

"Civil engineering has made substantial changes this year in reducing surveying and drawing requirements."

"Our Civil Engineering Department has thrown out several arts type courses, has increased its mathematics content to that required in all other engineering curricula, namely, through differential equations."

"Part of the opportunity for the improvements has come about through a reduction in applied engineering courses."

"The greatest change has been the reduction in the engineering art courses such as shop, drawing, and surveying."

"Shop practice (was) discontinued."

"Elimination of the power and communications options from Electrical Engineering signifies that specialized courses are giving way to fundamentals which are basic to all engineering."

"Industrial, aeronautical, engineering physics, and mechanical engineering have cut in half the number of credits in 'shop' and moved toward engineering science."

"Proficiency in the 'art' of civil engineering is left to post-collegiate development and on-the-job experience."

"The drawing-descriptive geometry has been reduced from 7 to 4 semester hours."

"Here are some of the courses which were given in 1950–51 but are offered no longer: General Engineering (a multi-lecturer survey course), Engineering Drawing, Applied Mechanics, Strength of Materials, Materials of Engineering, Heat Engines, Water Supply and Sewage, Mechanism, Elements of Electrical Engineering, Heat Power Machinery, Industrial Chemical Calculations, Technical Organic Processes."

"Our curricula have been revised extensively to eliminate all courses that were largely descriptive of the 'art' of engineering."

"We expect to give no credit toward our engineering degree for advanced ROTC in the future."

"Chemical Engineering reduced laboratory hours and credits in the course, Fuels and Lubricants. This was in the direction of reducing time spent on techniques."

"The engineering practice courses have been reduced about 10%, and a small opening (about 5%) has been made for elective courses."

"Several courses such as business law, survey of accounting, senior seminars, writing for professional men, report writing, composition, etc. (were eliminated) and more literature, great books, economics, political and economics world geography (were added)."

"A number of professional type courses and application courses emphasizing the practice of engineering have been eliminated."

"Two years ago Engineering Drawing was changed from a two-semester course to a one-semester course. Next year it may be dropped as a required course, but will be retained as an elective."

"The College of Engineering does not substitute ROTC courses for any of the courses in the engineering curricula."

"Since 1956–57 advanced ROTC is not counted in satisfaction of the engineering curriculum."

"The shop courses and the surveying course previously required for all freshman engineering students were completely deleted from the program."

"A 2 credit hour course in mechanical laboratory given by the Mechanical Engineering Department is to be dropped."

"(We have) decreased the number of device-oriented courses."

"Specialized engineering courses like power plants, internal combustion engines, refrigeration and air conditioning, formerly required, are now technical electives."

"On recommendation of the Drawing Department, descriptive geometry was then largely deleted; and vector algebra took its place in the fall of 1957."

EMPHASIS UPON HUMANITIES AND SOCIAL SCIENCE SEQUENCE

(quotations from different institutional reports)

"The humanities and social studies requirement will consist of eight semester courses in addition to English composition."

"Not more than six credits of advanced military science will be substituted for work in the humanities or social sciences. This represents an improvement over our present situation in which we permit the substitution of twelve credits."

"This sequence includes the new requirement, all through the senior year, of a survey course of western literary culture."

"We have cut off some of the so-called 'hardware courses.' It is our feeling that we have strengthened the program for better living but on the other hand—graduate school for the majority is becoming an essential because of this change."

"We have not been able to increase our humanistic-social offerings because of military conflict which has not, as yet, been decided upon by the Administration."

"Over 25% of each engineering curriculum is devoted to elective, humanistic-social studies."

"(Humanistic-social and cultural electives should be) properly distributed among the following areas: (a) verbal and written courses including speaking, literature, and writing; (b) social sciences; (c) fine arts, language, literature and music; and (d) history, philosophy and religion."

"Addition (has been made) of more humanistic-social studies in the junior and senior years."

"The Humanistic social studies (have been) completely revised with a required total of 45 quarter hours of 28.1 semester hours."

"The humanities have been substantially increased, more than doubled in credit hours."

"Humanities have increased from approximately 20% to 26%."

"By increasing to approximately 8½ semesters of required work, time has been allowed for additional work in humanistic-social studies."

"We are quite pleased with the humanistic social content of our curricula. We require 30 semester hours, including freshman English 6 hours."

"Addition of more humanities to the engineering curricula and removal of general descriptive courses (was accomplished)."

"We have added one hour of freshman English in all of our engineering programs. We have also rather uniformly set out approximately fourteen hours of electives in the areas of humanities and social sciences. This is in addition to required work in English, speech, and economics in all of our curriculums."

"Our requirements in general education are to be increased."

"Three hours per week in an 'Introduction to Humanities' course and two hours per week in a sociology course—both for the entire year—replaced the former English course of the first year."

"Humanities and social science will be increased considerably in order to bring us to about one-fifth."

"Some progress has been made in increasing the credits allowed for the humanistic-social studies."

"The humanistic-social study requirement remains at 22% of the total engineering program, which is essentially the same as it has been for the past 35 years."

"In addition to two courses in English, all engineers take seven elective courses in the humanistic-social science group."

SOME GENERAL COMMENTS
(from different institutions)

"There is little in common between the catalogue material in 1953 and the 1958 version."

"In place of these and other deletions are uniform requirements for not less than three full years of mathematics, two of physics, and one of chemistry, plus humanities and social sciences."

"Courses in manufacturing processes and materials, courses in production processes and in materials for all engineers except chemical have been revised and combined and start off with the atomic structure of metals and simple equilibrium conditions."

"The important engineering curricular changes that will appear in the 1958 catalog are that more mathematics will be required; more humanities and social sciences will be required."

"The trend in all of these minor changes has been to increase the hours allotted to humanities and non-technical electives, and to improve and adjust courses in engineering science."

"No free electives were listed in the 1953 curricula; in the 1958 program nine elective credits are included in the civil engineering curriculum, three in the electrical engineering curriculum, and six in the chemical engineering curriculum."

"Science requirements have been increased from 52 to 65 quarter hours."

"This group has been striving for a program which would provide greater emphasis on the basic sciences, more hours of electives, the elimination of survey type courses, an increase in the number of engineering science courses common to all departments, and a reduction in the number of different courses taken in the freshman year."

"The scientific content of the program has been definitely raised, perhaps by as much as 10%, without corresponding inroads in the humanistic stem."

"Our entire endeavor is to revise the curriculum with a scientific core for all branches of engineering."

"Any report that has produced as much discussion both pro and con is bound to have extensive influence on the thinking of even those that disagreed most."

"(We) require trigonometry and so-called college algebra for entrance."

"Entrance requirements to the College of Engineering have been tightened."

"It appears quite likely that the mathematics requirement for admission will be raised."

"First of all in 1957 the entrance requirements have been increased so as to include mathematics through analytic geometry."

"Requirements for entrance to the college are being increased from 3 to 4 years of high school mathematics."

SOME NEW CURRICULA OF UNIQUE CHARACTER
(reported by different institutions)

"A curriculum in Engineering Science and in Engineering Physics has been instituted and we find that these two curricula now have enrolled our best students who will make outstanding records. We have found likewise that industry needs a limited number of these students and that they are very anxious to hire our students in this category."

"I am including a copy of our new Honors Program in Engineering Sciences."

"A Nuclear Engineering Option in the Metallurgical Engineering curriculum. Next year there will be offered a new graduate program, Master of Science in Nuclear Engineering."

"A new curriculum in Environmental Engineering has been developed to replace the old Sanitary option. The new program is heavy in basic science courses and suited to the problems of industrial wastes, radiation hazards, etc."

"Our Nuclear Science and Engineering program offers an indication of the trend. This is now a major activity. We have carefully avoided establishing a new department in this area, because we believe that nuclear science and engineering is simply modern engineering and not a new profession."

"Work in Nuclear Engineering has been added."

"A new department of Engineering Science was established. The new curriculum in Engineering Science incorporates the concepts of an engineering curriculum designed to educate students for creative work preparing them thoroughly in basic science and mathematics and introducing them to the general field of engineering without excessive specialization."

"One five-year program combines a Bachelor of Arts degree in Mathematics with a Bache-

lor of Science degree in the students' chosen field of engineering."

"Bachelor of Engineering Mathematics (has been added)."

"Bachelor of Science Degree in Applied Mathematics (has been added)."

"Two years ago we introduced a new curriculum in Engineering Mechanics which is more highly mathematical than any of the other engineering curricula."

"A new curriculum, Engineering Sciences, has been added."

"We also agreed that our degree designation should be changed from Bachelor of Engineering to Bachelor of Engineering Science."

"Engineering Science: This (new curriculum) includes the fundamental Civil Engineering courses with a liberal amount of courses in Physics and Advanced Math."

"A curriculum in Engineering Mechanics leading to the B.S. degree (has been introduced)."

"A curriculum in Aeronautical Engineering has been added. Several new courses in aerodynamics have been added, and there is appreciably more emphasis on basic science than was the case in the old aero option."

"New curricula introduced within the period are Nuclear Engineering and Metallurgical Engineering."

"A new curriculum in Engineering Mechanics will be inaugurated in the fall of 1958. This curriculum is designed primarily for those interested in research and development careers in the field of engineering."

"We have added options in engineering physics in what we call Mathematical Engineering, which deals with applied mathematics and machine computations."

"A new curriculum in Engineering Science was established in 1953 and the first class was graduated in 1956."

"In Aeronautical Engineering two options have been added—Airborne Systems and Aircraft Option. Electrical Engineering—Aero Systems Option."

"We have introduced an option in our Engineering Physics curriculum, Nuclear Physics."

ASEE AT NUCLEAR CONGRESS

John Roberson, new head of Associated Midwest Laboratories, will be the speaker at the ASEE luncheon at the Nuclear Congress in Cleveland in April. The luncheon will be Wednesday, April 7.

The 1959 Nuclear Congress will be held in the Cleveland public auditorium April 5–9. Theme of the congress, which will be sponsored by more than 30 engineering, scientific, and management groups, is "For Mankind's Progress."

COMINGS DEAN AT DELAWARE

Dr. Edward W. Comings, head of the school of chemical and metallurgical engineering at Purdue University since 1951, has been appointed Dean of the School of Engineering at the University of Delaware.

Dr. Comings succeeds Dean William W. Hagerty, who left the University of Delaware on August 31 to accept the deanship of the School of Engineering at the University of Texas.

ENGINEERING EDUCATION AS IT AFFECTS UNITY IN THE PROFESSION

FREDERICK C. LINDVALL

Chairman of Engineering, California Institute of Technology Pasadena, and President of ASEE, 1957–1958

A talk presented at the convention of the American Society of Civil Engineers in Portland, Oregon, June 25, 1958. A modified version of this talk is to be published in ASCE's Journal of Professional Practice.

Unity to have meaning must have substance. More than an occasional rally to common action, an affirmation of faith as an engineer, a statement of principles of ethical practice and a loose confederation of our several professional societies is necessary to unity. Indeed these factors would follow as consequences of true unity rather than as means for achieving it. Rather, the powerful cohesive forces of common objectives, common education and mutual understanding should permeate all engineering practice, education and relations with the public.

These unifying influences must stem from a basic understanding of our profession and its service to mankind, the creative nature of its work, the interplay of basic science, analysis, and design, and the social and economic evaluation of new engineering systems and projects. Through identification and extension of the common substance of engineering we must create this common base of understanding without which no truly professional status can be achieved.

We must be engineers first, with a specialist designation second in our thinking and attitudes. Psychologically the title "Engineer" should have the greater appeal, rather than the narrower designation of "Electrical Engineer," "Civil Engineer" and so on. Our medical friends with their greater professional unity are, first of all, doctors of medicine, regardless of specialization. The professional identification is Robert Smith, M.D., practice limited to Pediatrics, or John Roberts, M.D., Radiology. This radiologist has his specialized journals, a radiological society, and professional intercourse with other specialists in his field. At the same time he has his identification with all other medical practitioners. By analogy, an engineer might list himself as Robert Smith, Eng. Foundation Engineering, or John Roberts, Eng. Structural Design. But is this just quibbling, setting up a distinction without a difference, playing with words? I think not, because the psychological implications are quite basic, particularly so for the student and the young engineer, who seek the satisfaction of group identification. If this group represents solely a specialty rather than a unified engineering profession, the young mind will be channeled from the start and will tend to reject the broader and more powerful aspects of engineering. This broader approach also suggests an education which is more fundamental and more comprehensive than at present.

The Concept of Unity

The basic concepts of unity and common subject matter must come early and continuously in the educational experience of the young engineer. Academic curricula follow the pattern which was established many years ago, paralleling quite closely the

professional engineering societies in name and objectives. Professional societies have splintered from a single split between military and civilian engineering to more and more detailed subdivision and classification. Similarly, college curricula have tended to proliferate, usually copying what appeared to be a trend in industry and after the fact rather than in anticipation of fields of specialization. Thus it is not uncommon at a large university to find at least a dozen colors and flavors of engineering education, not including some of the inter-disciplinary curricula such as engineering physics, engineering science, applied physics, applied mechanics and so forth.

Despite the insistence of educators that all engineering has a strong common core of basic science and the engineering sciences, and that only minor differences give identity to the various curricula labels, the student remains unconvinced of the unity of engineering. He cannot help but be impressed with the industrial engineering professor making industrial engineering seem different from mechanical engineering and the structural engineering professor emphasizing heavy walled sections while the aeronautical structures professor is directing the student's attention to thin walled structures. The electrical engineering professor who is interested in power talks about transmission lines as though they were fundamentally different from the transmission lines which the communications professor describes.

The differences extend also to the so-called service courses which one engineering department gives for students from other options. These service courses are frequently warped to conform to what the customer thinks are the needs of his students, rather than leaving to the judgment of the other professor the subject matter which he deems right for the non-specialist in his field. The net result is that these service courses tend to be something which the students take under protest without ever appreciating the fact that much of the strange material may be familiar stuff, only in a strange language.

Unity Early

In the first two years of engineering education the students are largely in the hands of non-engineers who present the basic courses—physics, mathematics, chemistry, English, history, etc., with no professional engineering concern. This is instruction for two years in subjects which for most students are merely the acquisition of skill, learning of principles, techniques and means to the end, that is, to the engineering courses which are to follow. The student gets no feeling of engineering unity or coherence, except the general feeling that all engineers need some physics, all engineers use mathematics to a greater or lesser extent, all engineers should be able to read and write. In some schools an attempt to alter this situation appears by having Freshman Engineering Orientation, Engineering Problems, Elementary Engineering Analysis, or some such title in which members of the engineering faculty have an opportunity to present representative engineering problems to the students, problems which are sometimes of rather broad scope but for which the student is not expected to be ready to analyze details.

Then under our typical departmental academic organization the division of students into options occurs. In fact some schools, to hasten specialized professional orientation, introduce departmental subjects in the sophomore year with the Electricals separate from the Mechanicals at that level, if not in the freshman year itself, for example. From then on, the

student is completely channeled except for some common subjects which all engineers take, although not necessarily with the same scope and intensity. Applied mechanics is one of these. Unfortunately, in the United States, Applied Mechanics in engineering schools has meant essentially a course of rather limited scope, covering statics, dynamics and strength of materials. Only recently have some schools begun to use the broader concept of applied mechanics which has long been common in Europe, in which such topics as elasticity, fluid mechanics, vibrations, etc. are all included. Here important generalized concepts and common ideas are not lost as they tend to be in some of our neatly packaged courses.

Our historic curricular arrangements have merit, but they are not necessarily sacred. In the ASEE *Report on Social-Humanistic Studies,* a very penetrating remark is made: "Reorganizing an academic curriculum is like trying to move a graveyard." We have tradition, sentiment, even reverence for present values, real or presumed, in existing curriculum objectives and patterns. We have "vested interests" in certain courses, syllabi and textbooks, as well as the human reaction to receive a proposal for change as a personal criticism of present teaching. We also discover that some alumni become disturbed over changes in the educational pattern often through misunderstanding and misinformation. Likewise, the professional societies whose names are so closely identified with the labels of our standard engineering curricula have profound and proper concern for education which is consistent with their professional objectives.

New Developments

As professional men and as educators we are immersed in a rapidly changing technology. In the past ten years a whole series of new developments has stimulated profound changes in some engineering curricula. Radar, microwaves, semi-conductor devices, magnetic amplifiers, jet propulsion, nuclear energy, some of which were war-born, have introduced new information, new theory, principles and applications into college work. As a specific example, microwaves and their associated wave guides have brought Maxwell's electromagnetic equations into undergraduate classrooms and required an extension of mathematical preparation to comprehend the analysis and understand the behavior of these ultra-high frequency systems. Another example is the digital computer, which has good and bad effects on engineering colleges—good because of the intellectual stimulus and broadening of the mathematical base of engineering, bad because much time can be wasted in a maze of details which are apt to be transient in the fast moving computer game. The computer is being recognized by structural engineers as a powerful tool for analysis and design. Many alternative designs can rather quickly be studied and the effect of changing parameters can easily be learned. Hence, optimum designs can be identified without prohibitive cost in engineering time. More thorough analysis will allow closer approach to ultimate limits with assurance and comfort. These advantages will motivate civil engineering students toward more mathematical competence in the understanding of computer logic and techniques for later use. Similarly, a broader mathematical foundation will strengthen a designer's capability in dealing with dynamic structural problems arising from transient loads of traffic, wind, earthquakes or blast. Closely related are the vastly improved instrumentation techniques for static and dynamic

stress determination, experimentally, during construction, and periodic measurement during the life of a structure. Strain gages and other transducers are now found in college testing laboratories along with their necessary electronic amplifiers and recorders, broadening the student's horizons to include more comprehension of basic electrical engineering. Rapidly this modern instrumental approach is transforming the traditional "busting laboratory."

Obviously, we can't go in all new directions at once. We cannot, and I believe, should not, attempt in the colleges to meet these challenges by detailed specialization in all of these new and emerging areas of current interest and importance. We must, instead, do the more difficult job of examining each new development for those features that are truly basic, extracting the concepts that are new and fundamental, and synthesizing the important generalizations that have lasting value. This exercise of self-discipline, sticking to fundamentals, is not easy. The other course, that of following avidly in the classroom the exciting new developments, the intriguing applications, and the fascinating new details, is more fun, has high entertainment value for the student, and is an easy, pleasant way to teach. But it has the elements of a phony gold brick, the superficial appeal—the form, but little substance. The values are apt to be transient.

Thus, in appraising new developments, engineering colleges must evaluate critically the fundamental character of these new advances—what is now involved and what is anticipated —so that curricula and course content of the basic sciences and engineering sciences may be improved as fundamental education for future professional application. We must always be critical of that instruction which is specialized training rather than comprehensive education.

Unity of Principles

The business of a university is to teach principles, not practice. Details are to be regarded as illustrations of the application of the principles. With such underlying philosophy we can make our engineering teaching have much broader professional scope. An example is systems engineering.

Systems engineering describes good engineering procedures for achieving an optimum design or snythesis of a complex system, including the environmental factors and the people concerned in its operation. The basic principle is inherent in all good engineering and it was well stated some 70 years ago by A. M. Wellington in his classic volume, *The Economic Theory of Railway Location.* Wellington has this to say about reconnaisance, which one might paraphrase to apply to a system: "That, however forbidding the region, a line exists which is conspicuously better than any other, and which will in all cases be found to be—in comparison with what was expected—a line cheap to build and economical to operate; and that, on the other hand, the line which he, as an inexperienced man and acting without special training for the work, will be likely to first select as the best, is perhaps twice as costly in first cost and considerably less favorable in gradients and operating value than that which he can secure by greater care, attention and study. Although this may seem a sweeping generalization, it is so near a general average of probabilities in both easy and difficult country, that in a rude way it may be assumed as truth."

It is indeed ironical, then, that within civil engineering itself narrow professional specialties inhibit the

broad thinking outlined by Wellington. One of our Caltech faculty is currently assisting in the program of the Hydraulics Division for the 1959 ASCE National Convention in Los Angeles. He tells me that: "A very interesting paper has been proposed on a new procedure in evaluating aqueduct routes. Because this paper cuts across the fields of several committees and several divisions, there appears to be no place for it on the program." What has happened to our broad engineering principles?

Such broad principles are of value to electrical, mechanical, civil, aeronautical engineers alike. These are the things which make us all truly engineers, and, difficult as it is to do so, we must try to identify for our students these strong unifying influences.

Hence, I am not encouraged by the Report of the ASCE Task Committee on Professional Education. Conclusion (1) states:

> Civil engineering has certain characteristics which distinguish it from the engineering profession as a whole. Among these are breadth of field and the responsibility for economic planning, greater concern with public works and with countless structures serving the public welfare, and the development of plans and programs extending far into the future.

Followed by the recommendation, which is:

> Although certain undergraduate courses are commonly required for all students in engineering, civil engineering curricula must maintain their separate identity and objectives and the civil engineering departments of our colleges should receive support consistent with the civil engineer's great contribution to society.

I know that this attitude has long been a part of the philosophy of civil engineering education and it has a measure of validity. However, I cannot but feel that other fields of engineering also can fit into this broad context. Mechanical and electrical engineering, together with the many other variant forms of engineering practice, include long-range planning, responsibility to the public, and economic planning. The engineers in an automotive company who are engaged in the advanced designs are making plans for at least five years ahead. This may involve an entirely new factory with its integrated facilities, and, as an example of detail, an engine block design which is capable of progressive modification, rather than complete redesign as yearly models come along. Aircraft engineering is on an equally long time base with six or seven years elapsing from the concept and performance specifications of a new plane until it is operational. Public safety and health at altitude present problems of considerable magnitude, as well as relationshsips with federal and other regulatory bodies, not to mention compatability with radio navigational systems, communications and airport facilities.

Unity in Management

Engineers in industry are more and more assuming positions of managerial responsibility and, along with financial and legal talent, are shaping corporate policy. This involves very long range planning including many of the features that are normally associated with civil engineering projects.

It is not at all uncommon in large corporations as they expand to decentralize and establish new plants in communities where that type of industry may not have existed before. This is done for reasons of decentralization to tap new labor markets, to achieve better living conditions for employees. One of my former students, an electrical engineer, a few years ago was told by his company

management that they wished him to be the manager of a new plant for which he would have complete responsibility for design, construction and operation in a community which had essentially no industry at that time. This electrical engineer spent many months in negotiations with the local Chamber of Commerce, the banking interests, the city officials, the school officials, railway and highway people, to plan for the various services and utilities which would be required by this multi-million dollar plant and for the housing and school needs of the several hundred key employees who would be moved to this community. This kind of breadth is needed in many engineers who are facing similar problems in our expanding technology. More and more community problems of government, schools, recreation facilities and other environmental factors become key issues with employees who are being asked to move to new locations. The engineering manager must be very alert to these factors and have working with him people who are skilled in such matters. This and other attributes dealing with people and the attendant responsibilities should be marks of any truly professional man. By implication in this ASCE conclusion and recommendation, the civil engineers suggest that other engineers are less concerned than they with public works and structures, serving the public welfare and the development of plans and programs extending far into the future. The ownership is irrelevant.

A chemical engineer friend started eight years ago for his company to develop processes for a plant for production of chemicals from coal as raw material. This has been a truly long range development beginning with a new concept of remotely controlled mining of the coal, conveyor transport for some thirty miles, and processing as feed stock for the plant. This even involved negotiations and agreements with the union of mine workers who would not be needed! In parallel the chemical laboratory work was proceeding, leading in turn to the design and construction of the pilot plant. Concurrently preliminary design proceeded on the production plant. Electrical power, water supply, waste disposal, gas and chemical storage, fire protection, plant safety, instrumentation and control, transportation, all presented special problems involving not only the company but the community as well.

Mechanical and electrical engineers are planning years ahead for electrical power developments and communication systems to meet the needs of our growing technology and are raising standards of living. Our buildings both public and private have come a long way from being simply structures more or less decorated in which people worked and lived. Now within our structures we create a proper environment for the purposes of the building, with lighting, air-conditioning, communication and transportation devices of considerable complexity. One has only to look at the breakdown of costs in a modern building to see that the major effort goes into the mechanical and electrical aspects of the building and only a small fraction into the structure. People live and work in this artificial environment and it must be right. As one mechanical engineer I know who built a very large and successful manufacturing business has said: "The most expensive thing I buy is my employees' time, and if by additional investment in a better environment I can get only a slight improvement in work efficiency, I will be ahead."

No, some of these qualities of a good civil engineer are no longer

unique to civil engineers, and as a consequence—are the various engineering departments wise in trying to maintain artificial distinctiveness? Also, we must recognize that many of the qualities which make an engineer effective in dealing with the public, government officials, boards of directors, and so on, are not the result of study of college courses, but are due to his genes.

Unity in Complexity

In general engineering work is becoming complex, requiring broader scale systems thinking and analysis. This means that the responsible engineers must have rather broad knowledge of not only machines, but also the environment in which the machines must work and the men who will be concerned with their use. Students must learn to think more broadly than they have in the past, not that they can expect to be experts in all technical fields, but that they have a wider knowledge of what exists in these other fields and where their own ignorance requires that expert help be brought in. Therefore, we should not let our students grow up with the idea that mechanical engineers are markedly different from electrical engineers or from civil engineers, but, rather, that they are all engineers with some specialized professional slant. It is in practice that the engineer develops true professional competence and specialized knowledge.

College teachers badly need help from the professional societies if they are to convince students that unity in the profession is possible and that it is wanted. Do students see an attitude that is really professional and not merely provincial? Much can be done in engineering curricula to develop better attitudes toward unity without abandoning our engineering "options." This we accomplish by minimizing differences, developing similarities, common subject matter, common principles. We can interchange teachers across departmental lines and develop broad systems thinking. We can stress functions, rather than the traditional specialized disciplines to which the modern engineering world no longer conforms. We must provide better engineering *education* and not specialized *training* if we are to achieve professional stature and with it professional unity. We need your sympathetic understanding and active support. Then we can have education as it *effects* unity in the profession of engineering.

ELECTRONIC CONTROLS AND TRAFFIC SAFETY

Electronic Controls and Traffic Safety, background papers and final report of the Conference on Electronic Controls and Traffic Safety held last May in Harriman, New York, is available from the Safety Education Project, Teachers College, Columbia University, New York 27, New York. This project was founded in August, 1957, through a grant of $50,000 from the American Automobile Association Foundation for Traffic Safety.

A PHILOSOPHY OF ENGINEERING EDUCATION

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To many professional engineers and educators, the period 1939 to 1943 represents a significant turning point in the profession. Important technological and scientific developments were accelerated and brought into focus. The adage "necessity is the mother of invention" became a reality, and the engineer and scientist were called upon to provide that necessary for national survival. Such a situation has continued to exist over the past fifteen years, again largely as a result of the national defense effort.

Regardless of the cause, however, the engineering profession has been faced increasingly these past fifteen years with new and complex problems. From the viewpoint of the engineering educator, not the least of these problems involve increasing enrollment, staff requirements, curricular changes, and facilities. All, however, result in a need for educational program-planning.

In the field of mechanical engineering, for example, the engineer is faced with new problems of heat transfer, energy conversion, and fluid mechanics as a result of the interest in gas turbines, rockets, and jet-propulsion. Metallurgy is being built of necessity ever more firmly on a foundation of physical chemistry and physics of the solid state, in its search for materials to withstand the high temperatures required by new developments.

Civil engineers are coming to realize that greater scientific knowledge is required in the study of structural problems related to vibrations and soil conditions. New problems associated with the control of reactors present a real challenge to the electrical engineer. New and expanded generating and distribution systems require that the electrical engineer entering the power field be able to project his knowledge beyond a superficial understanding of currently existing equipment and system arrangement.

Digital and analogue computers have opened up new areas of analysis and design to engineers. Control systems for aircraft traveling at supersonic speeds, guided missiles, earth satellites, and manufacturing processes either are or are becoming extremely complex; advances in this field require that engineers have an education based both on engineering sciences and the pure sciences.

Further, as a result of this change in need which has come about so rapidly, the time lag between the discovery of new items in science and their application to engineering systems has been drastically reduced. The engineer of tomorrow, therefore, must be equipped to effect this rapid transition. The scientific training of yesterday was based on the pattern of slow evolution by individual development in pace with the existing transition rate from discovery to application. This pattern can no longer be assumed to exist. Thus, the coupling of this factor with the ever-increasing fund of knowledge results in an unquestioned need to reorganize training methods to incorporate more of the scientific approach to engineering. This includes not only an increase in emphasis on fundamental principles and mathematical tools, but also in-

struction in the use of these principles and tools in their application to engineering problems.

Effect on Curricula

The engineering curricula of the early part of this century were well designed and presented to satisfy the needs that then existed. These needs have now changed radically in an almost revolutionary manner. Volume of knowledge and time have both entered the picture to dictate changes. Without the type of international situation which has existed over the past fifteen years, these changes would have been gradual, but they would still have occurred. The speeding-up process, as a result of the situation, has merely advanced the date and made the need for action more imperative, and shortened the time in which such action must be taken.

Although engineering teachers are now beginning to get an inkling of the educational pattern needed to enable their graduates to meet these problems of the future, the accelerated time schedule introduces elements of confusion and a disruption of old, established ideas. This is a superficial condition, however, and progress is being made which will evolve into an adequate educational program. Those responsible for and engaged in planning, designing, and teaching programs of study for the education of our future engineers are faced with a tremendous assignment and responsibility—and an inspiring challenge.

Probably never again, however, will engineering curricula be stabilized in the sense they have in the past, nor should they be. Only through fluid change can engineering education maintain step with engineering progress and assist in its continued development.

The word "teaching" is fundamentally misleading; one cannot teach subject matter, one can only instill a desire for learning. The student must be led to want to learn, and to know how to learn. Only by injecting into him a philosophy of learning can we expect him to continue to grow and develop after graduation. Four short years is not nearly enough time for him to learn all he needs to know for his life's work, even disregarding developments which will take place after he loses contact with his formal education. Thus in planning a curriculum, a basic objective is to teach the student to think; to expose him to a series of fundamental principles; to utilize current developments as illustrations or vehicles to demonstrate the manner of applying these principles to the ultimate production of a desired device; to inject into the student an awareness of the art of engineering as it relates to the science; and the realization that the art can only be acquired with actual experience. Through such an approach the teacher can accomplish the maximum in terms of the effectiveness of the overall product.

Above all, the student must learn principles and not details of devices. The life of a device before obsolescence varies greatly depending upon the individual case. It has been estimated, however, that an average figure of somewhat less than ten years may safely be applied—certainly a short time compared to the useful professional life of the engineer. A detailed knowledge of devices, therefore, is not an education of any great permanency. A knowledge of fundamentals, on the other hand, is basic and lasting. The student who grasps these can project his knowledge to the next device, replacing the obsolete one used in his classroom as an illustration. He is prepared to cope with, understand, and even initiate advances

in the art and science alike.

To plan any program of education properly, however, it is necessary to have an idea of and to take into account the various types of work performed by the graduates of that program. One must also establish a definition of engineering. One such definition follows:

> Engineering encompasses the application of the various principles of the sciences, combined with experience, to the study, design and development of engineering systems composed of circuits, energy converters, structures and processes in various combinations. It is concerned with the analysis, synthesis and prediction of the behavior of these systems under specified conditions, in terms of function, personnel, cost, materials, time and safety. It is concerned further with the welfare of mankind, individually and collectively, and directs its efforts in pursuing the above activities toward an improvement of man's welfare, conveniences, and standard of life.

Types of Product

Graduates of a program designed to conform to this definition will do widely varied types of work. It has been postulated that they may, however, be divided roughly into five general groups:

Designation	*Percentage*
a. The engineer-scientist: These engineers are creative and devote their major attention to the discovery of new facts about engineering systems and to the recognition of those scientific facts which will lend themselves to engineering development.	5 to 10
b. The creative design engineer: These are the individuals who actually design new engineering systems and put newly discovered principles to use.	10 to 20
c. The functional engineer: These are the engineers who employ orthodox methods and established principles in the design of conventional details of manufacturing plants and public utilities, and they build, operate, and maintain these plants and the related equipment.	40 to 50
d. The engineer technician: Engineers in this group devote their attention to the more routine tasks such as testing, inspection and analysis.	10 to 20
e. Engineering graduates in non-engineering work: A large number of engineers in each of the above categories find themselves, perhaps ten years after graduation, in administrative, executive, or ownership posts in industry, government, and utilities.	5 to 10

In designing a program, therefore, engineering faculties immediately find themselves in a dilemma, which is further confused by the varying comments of industrial representatives, usually of small companies, who offer sincere advice on how a program should be planned. It is generally felt by educators and representatives of industries employing the majority of engineers, however, that curricula can be devised which incorporate the philosophies above, and which will come reasonably close to satisfying the needs of all concerned.

Perhaps the most widely adaptable

four-year graduate in engineering would be one who had been trained for what might be termed "consulting engineering." Such a student has been given an appreciation for the application of the fundamental laws, concepts, and techniques to the solution of engineering situations. With this appreciation and embryonic ability he may go into various types of industry in various capacities equipped to meet the problems which will face him realistically and not be submerged by them if they cannot be solved by textbook formulas. He is also well prepared to continue in graduate work.

Such a student, or rather graduate, will be capable of interpreting the physical significance of a problem, will be able to reason through the various ramifications of the situation facing him, and will be able to evolve a reasonable solution based on his composite knowledge, interpretive ability, and reasoning skill. This could not be done if his knowledge consists only of a collection of formulas, for it must be remembered that the average text problem, and, unfortunately, partially because of time, the customary quiz problem involve only a small portion of an engineering system.

A student who has been exposed only to this latter type of single problem analysis and solution is in no position to assemble the material illustrated in segmental form into a unified picture for the solution of an overall situation. He has built, or had built for him, a house with no stairs or connecting doors. He can perform within these rooms, or on the separate floors, but has no way to make the connection or combination of various areas. Such a graduate must, after graduation, be reoriented to accomplish this or else be relegated to the more mundane engineering operations, and viewed as a technician.

Such a training is not necessarily inherent in, or even related to, course content. Unfortunately, in many course areas it is even discouraged unless supplemented by the instructor. The engineering of the past has not demanded this unified training, though our progress would have been greater had it existed.

It is therefore imperative in presenting engineering fundamentals that real attention be given to injecting a feeling for the physical significance of the relation, its relation to other fundamental principles, and the manner in which these relationships may be combined for application to broader situations.

A student needs to be given a certain amount of drill or formula-plugging, perhaps, to make him familiar with techniques of solution, to fix in his mind the relations being studied, and as a motivation through the feeling of something accomplished. This is more necessary at the early level, however, than later. Early in the instructional curriculum a start must be made in giving the student problems which will require his reasoning through a situation and one which, while solvable by use of known formulas, represents a need for him to interrelate fundamental principles.

This practice should be expanded as the courses and curriculum proceed. At the end of his program of undergraduate study, not only should he not fear being faced with such situations and realize that these represent true engineering problems, but he should habitually orient his thoughts toward a proper attack utilizing all the background information he has acquired.

This is an instructional problem that cannot be solved merely by an improvement in textbooks, elimination of or change in course content. It is not important that a student

know something about everything in a course or curriculum; it is important that he know how to use what knowledge he has acquired in attacking a broad problem.

If this were not true there would be little or no reason for an electrical engineering curriculum, for example, to include such courses as mechanics or thermodynamics. Time would be better spent on drill or localized problems or in the study of details of specific devices. An electrical engineering system involves, on the other hand, factors affected by all these areas. The student or graduate, then, has supplementary non-electrical information which is important in the solution of the situation and which he must be able to relate to it.

Thus, it is not a matter for discussion as to whether an engineering curriculum should be four years long, five years long, or more except, possibly, for the sake of student maturity. It is important that each course in the curriculum, regardless of area or content, be presented in such a way as to develop real analytical ability in the student, and from this, encourage creative thinking on the part of the student. True creativity is a characteristic which relatively few graduates will acquire. Through training of the nature described, however, it is more likely to be developed, and sooner, than otherwise.

Levels of Teaching

It must be emphasized that while a course may have an accepted name and description, it can be taught at many different levels and in many different ways. A course may be criticized as encouraging the student to use formulas for the sake of solving problems—the "plug-in" course. The same course under a different instructor, however, will produce students who are developing the facility for thinking in terms of the demands of the engineering situation and are beginning to learn the meaning of analysis. They have grasped not just the use of the formula, but its significance. The engineering teacher himself, even more than the curriculum, controls the attitudes and actually the potential abilities of his students. It is necessary that the teacher recognize this and strive to project this philosophy into his lectures.

In order to keep abreast of developments in the area of his interests or specialty, the outstanding teacher accepts the concept of lifetime learning. He recognizes the importance of keeping up to date, and thus is able to keep his class discussions and lectures dynamic rather than static. One is often asked the question as to how the teacher keeps abreast of the times in the changing technology of today. There are several ways which could be mentioned; however, another fact must be considered before the question can be adequately answered. Engineering is both an art and a science. The professional skills and techniques of engineering are acquired only through experience with actual engineering systems. In the normal four year program of engineering education, time permits the faculty to impress upon the student only the importance of the art of engineering and to give him a strong foundation in the fundamentals of physics, chemistry, mathematics, and the engineering sciences.

An engineering faculty usually consists both of what one might term academic engineers and professional engineers. The majority of engineering staff members, taken nation-wide, is of the academic type since most of them have in general had little or no professional engineering experience in industry on a continuing basis. Because these two types vary considerably, there are two distinct avenues for professional development. The

teacher who is of the academic type usually develops his stature through research activities, scholarly writing, and the creation of new techniques and aids. The professional engineer's interests are slanted toward the solution of actual problems in industry. His growth comes about through active consulting work, one measure of which are his reports to industry.

Either type of activity enhances the teacher's stature. It is unfortunate, but true, that there are some teachers who for one reason or another are satisfied to maintain their professional standing at a fixed level, and consequently do little with regard to self-improvement activities. The strength of a faculty depends in large measure on the number of teachers who actively strive to enhance their professional stature through research, creative writing, consulting work, and so on. To make these activities possible, however, staff loads must be such as not only to permit, but to encourage participation.

Engineering educators throughout the country are taking a critical look at their respective curricula. They are attempting to evaluate their program in the light of changing requirements. Each group is attempting to meet the needs of the present and the future in its own way. Thus at this point we have, over the country, a wide variety of engineering programs which we might term experimental, but based on sound philosophy. Some of these have gone to greater extremes than others; some have been hesitant to take major steps; others have made little or no advance partially because of the unwillingness of the staff, or influential members of the staff, to face the situation squarely and do the work necessary to make the adjustments.

In all cases, however, where changes are being made, they are being made on the basis of the philosophy outlined above, or variations not differing greatly therefrom. In a very few words, they are based upon the increase in and integration of the presentation of fundamental principles, with an attempt to inject an appreciation for the art of engineering. This is being done by presenting more generalized aspects of engineering, and by selecting a central theme as the carrier for this generalization with the associated areas related as closely as possible to the basic aspects of this central core.

Some educators have said that we must look twenty to twenty-five years in the future and attempt to determine what our present engineering graduate is going to be doing at that time, and then design a curriculum to suit this. This would be fine, but very few if any have the foresight or imagination necessary to make this prediction with any degree of accuracy. Just as there were many varieties of automobiles on the market in the twenties, and only a few of these have survived, one cannot predict the exact turn of technological development for the future. One can say, however, that the development of an active mind, the physical appreciation of basic scientific principles, and an understanding of ways and means of applying these principles to the development of a useful device, represent an education which is not of the trade school variety, and one which will leave the student with lasting knowledge and capabilities.

Results

One might summarize the comments and philosophies above into a list of objectives for an engineering program.

1. The student should be encouraged to appreciate the value of life-long learning. In other words, graduation from the university is only one step in his education. This objective may be accom-

plished by stressing the importance of the use of library facilities, attendance at professional meetings and conferences, and outside reading.

2. We should insist upon the student's developing his skills in the proper methods of communication of ideas through the use of his mother tongue, ability to portray his ideas in drawings and sketches, and facility in the use of mathematics.

3. The student should be required to develop an understanding of the important natural laws and concepts. The natural laws in physics, chemistry, etc. should receive greater emphasis. In many technical courses considerable time is devoted to the study of existing engineering equipment. The goal should be to develop capable engineers for the problems of tomorrow. Time now devoted to detailed descriptions should be devoted to enhancing the student's understanding of basic principles.

4. During the course of study, the student should be made aware of the fact that engineering is both an art and a science. All problems in engineering are not solved by means of equations or technical data. In many instances a great deal of experience is required. During a four-year period of study, it is not possible for the student to learn the art of engineering; however, it is essential that he be made aware of its importance.

5. Laboratory experience should be a part of the program, for it serves the following purposes:

a. Exercises which confirm theoretical concepts and the laws discussed in formal classrooms give the student a feeling of confidence, a conviction that the statements presented are truths. They should be presented, however, in such a way as not to mask the real purpose with undue tedium and unnecessary repetition. Further, the laboratory should extend rather than duplicate classroom work.

b. The laboratory experiences enable the student to see how well his ideal system predicts the operation of an actual system. This is a climactic experience which brings the classroom work into clearer focus.

c. By means of suitable experiments the student is afforded many opportunities to develp facility in the use of measuring instruments of all types.

d. Many students entering university work have had little opportunity to observe actual engineering devices in operation. The laboratory affords them a chance to make such observations under expert guidance.

e. By proper arrangement of student participation, the laboratory gives the student actual experience in managerial and organizational procedure. Student leaders who are responsible for the planning of the experiment and organization of the group derive a great deal of value from their experience.

f. The laboratory serves as a means by which the student develops skill in both analysis and synthesis.

g. Oral and written reports enable the student to gain additional facility in the use of the languages of engineering.

6. The student should develop skill in the use of modern computing equipment for the analysis of problems. The slide rule is no longer the sole symbol of the engineer's computing device, since it has been augmented by analog and digital computers.

7. The engineer should be familiar with the properties of materials used in his engineering systems. One of the main barriers to progress is related to materials problems. Prior to the war, industry was concerned with physical phenomena, while today much of the main emphasis is on materials. A knowledge and understanding of the chemical, mechanical, thermal, and electrical properties of solids, liquids, and gases and their interrelations is essential.

8. The engineering student should have a knowledge of regulation and control. All modern engineering systems involve some kind of control or regulating instruments. This objective immediately points out the need for experiences in systems analysis and synthesis.

9. The student should be acquainted with modern industrial processes. In the limited time available, it is possible only to introduce the student to a few such processes. He should be encouraged to take full advantage of inspection trips, and to seek summer employment in industry or with the utilities.

10. The program of study should be so planned that the student becomes familiar with the mode of analysis used by engineers, and is given exercises in the four general methods of attacking a problem, namely: experimental, analytical, use of models and analogs and finally in what might be termed the art. By art is meant the application of judgment based upon experience.

11. As the student progresses he should be encouraged to be on the lookout for ways of correlating and integrating fundamental knowledge. The more of this he can do, the stronger will be his foundation. Above all, the student must be taught to think clearly and logically and to learn how to apply his knowledge to new situations.

12. In order that the graduate engineer can enjoy the status of a respected citizen in his community and become a worthy member of his profession, he must develop an appreciation of other values too, such as those termed human, moral, social, artistic, economic, and professional. The undergraduate program should be designed to encourage the student to start the development of such a set of values.

If the objectives listed above can even partially be attained, the engineering educator will have succeeded in his task of producing trained men for the engineering activities of the future. It must be remembered, however, that a curriculum is merely a vehicle for accomplishing these objectives and that it is fundamentally the instructor who must see that the proper interpretation is placed and that use is made of the subject matter of the various courses. This is not an easy task. It involves appreciations, techniques, and abilities on the part of the instructor which require intensive preparation and leadership. These cannot be achieved without effort, but with responsibility for the professional lives of many students and indirectly the safety and living standards of all, education must make that effort and must strive to achieve the desired results.

RENSSELAER, AEC TO BUILD LINEAR ACCELERATOR

A linear accelerator will be jointly built by R. P. I. and the U. S. Atomic Energy Commission, it is announced by Dr. Richard G. Folsom, president of the Institute.

This research facility, located on the Rensselaer campus, will represent a total investment of about $2,500,000 and will require two years for completion. The accelerator, along with instruments and auxiliary equipment, will be provided by the AEC. The Institute will provide housing for the facility and an adjoining research laboratory.

CARNEGIE INSTITUTE OF TECHNOLOGY

Co-Host for 1959 ASEE Annual Meeting

Under the late Dr. Robert E. Doherty's revolutionary Carnegie plan, students are coached rather than "preached at," and are thus taught how to learn by themselves. This form of self-help has become a recognized trend in engineering education. Reprinted by permission from the London *Times*, July, 1957.

Revolutionaries are not generally rewarded with the admiration of their contemporaries, and in education advocates of drastic change are rarely received with enthusiasm. But in 1950 when the late Dr. Robert E. Doherty retired from the Presidency of Carnegie Institute of Technology in Pittsburgh, Pennsylvania, after fourteen years, it was agreed that he had handed over to his successor, Dr. J. C. Warner, and to American education a revolutionary success—the Carnegie plan.

For Carnegie Institute of Technology is not just another engineering college or university . . . it is the breeding ground for a new type engineer developed under a far-reaching but realistic plan for engineering education. The Carnegie plan is no longer Dr. Doherty. The Carnegie plan *is* Carnegie Tech and in the past seven years since Dr. Doherty's retirement Dr. Warner has continued and expanded its policies to the point where the experiment of twenty years ago has become a trend, recognized in an increasing number of engineering schools and professional societies.

Graduate School of Industrial Administration, Carnegie Institute of Technology, William Larimer Mellon, Founder.

The *New York Herald Tribune* recently said, "The Carnegie plan, an almost revolutionary departure from the long-established conception of engineering education, was founded on the central aim to teach students how to learn by themselves so that after college and for the rest of their lives they will be able to go on learning. The revolutionary Carnegie plan became Dr. Doherty's brain-child but it can safely be said that whenever a revolution turns into a brain-child it has become respectable and its contribution enduring."

The basis of the Carnegie plan is that it does not require students to memorize the maximum of information which might be offered to them in four years. Emphasis is placed on a relatively small core of fundamental, or root, knowledge which should be ready for use as the basis for solving specific problems as they arise.

Under this plan the faculty performs the function of coaching rather than of traditional "preaching at" instruction. Students are given the basic knowledge to produce their own answers toward the solution of specific problems. Carnegie rejects the prefabricated key or memorized formula which makes the student helpless in the face of unexpected situations. The

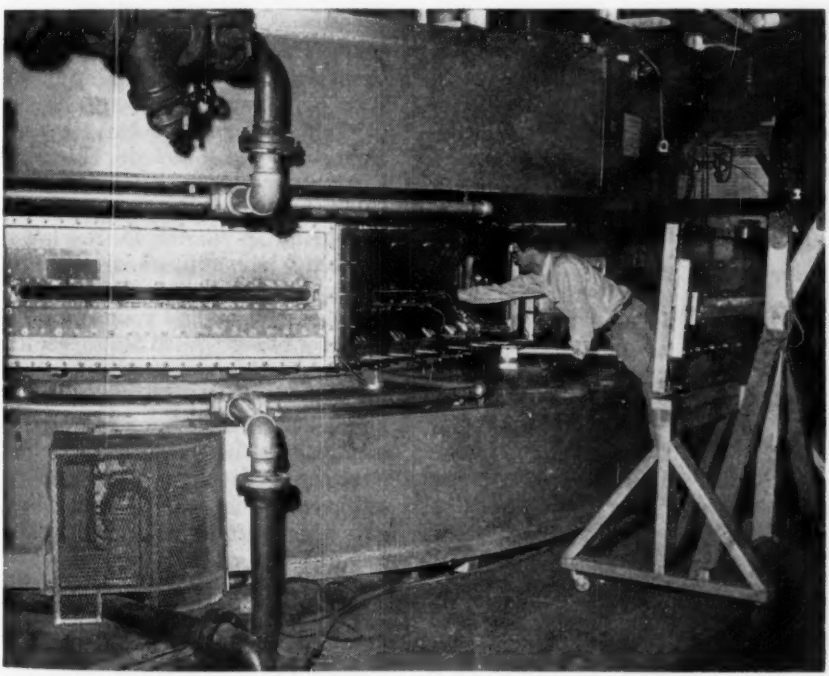
student is required to learn by tackling specific problems rather than sticking to texts and lectures.

A typical examination in a recent Carnegie course asked students to reconstruct the conditions of their lives and jobs had they been engineers in the Greek, Roman and Victorian civilizations of the past. In a beginners' psychology course, Human Relations In Industry, students are asked to solve problems involving not only cost and production but also the human dilemma of an injured worker and his family.

Briefly then, work at Carnegie consists of two inter-related groups of courses: the basic courses and the specialized courses. The basic courses are chemistry, physics, mathematics, English and historical, economic, and the psychological analysis. Together they help students to develop the breadth of knowledge, the fundamental understanding, and the power and method of analysis that will equip them to learn effectively in their specialized courses and to go on learning after graduation as professional men and as citizens.

"The most pervasive and insidious educational fallacy," Dr. Warner says, "is that education is achieved by merely learning subject matter: that the more ground covered in class—the more pages assigned in the book—the greater the education."

Undoubtedly Carnegie's leadership in this form of education is responsible for the greater demands being made upon the school. It has grown from 2,500 full-time students, before the war, to 3,300 to-day. More significant, perhaps, is the 400 per cent increase in graduate enrollment to the present number of 425. In addition to this



A research physicist at work on the 450 megavolt synchro-cyclotron. The vacuum chamber walls have been removed showing the bottom magnetic coil.

A front view of the College of Engineering and Science building.

full-time enrollment Carnegie points with pride to its 1,500 part-time students studying in the Evening Division. Indeed, some of its ablest alumni found their educational preparation in this area and many employees of Pittsburgh industry are upgrading themselves through evening courses to qualify for responsible positions.

The Carnegie campus is located four miles from the business center of the great industrial city of Pittsburgh. Its 70 attractive acres adjoin Schenley Park's beautiful woods, and one of the city's most attractive residential sections. At Carnegie, students enjoy a seclusion seldom found in a metropolitan area yet at the same time have all the benefits of a great industrial city within easy reach. Pittsburgh, the center of heavy industry in the United States, provides unusual advantages and opportunities for students studying engineering, science and management. There are frequent field trips to mills, plants, and research laboratories enabling students to study equipment and processes in operation through first-hand observation. Pittsburgh is, in this sense, a laboratory. Yet Pittsburgh is not entirely industrial for within walking distance of the campus is the city's cultural center offering the student great libraries, a museum of natural history, art galleries, a concert and symphony hall, lecture programs, and, nearby, a community theatre—one of the finest in the country.

Carnegie Institute of Technology's great accomplishments in education have been derived from its adherence to the principles of the Carnegie plan and its maintenance of the highest standards in selecting students and faculty members. In this respect Carnegie has been unusually successful. Each year more than 4,000 students apply for entrance yet only 800 new students are accepted. While it is normal for colleges and universities to proclaim that only students with outstanding records gain entrance, Carnegie quietly proceeds to get many outstanding students. More than 47 per cent of each entering freshman engineering class graduated in the top 10 per cent of their secondary school. Approximately 75 per cent were in the top 20 per cent of their secondary school.

The research and teaching staff at Carnegie Tech reads like a "Who's Who" and numbers 400—an unusually low ratio of one teacher for every eight students. It includes Dr. Robert F. Mehl, internationally famous in the field of metallurgy and metals research; Dr. Frederick D. Rossini, an authority on petroleum research; Dr. Everard M. Williams, recently named the most outstanding young electrical engineer in the United States; and Dr. Truman P. Kohman, recent discoverer of a long-lived radioactive isotope of aluminum. But first and foremost—as a university that teaches engineering students—its faculty are teachers.

The research and creative activity carried on at Carnegie is, however, an integral part of Carnegie's three objectives: undergraduate education, graduate education and research and creative attainment. In the college of engineering and science, substantial programs of fundamental research are conducted. There are several special

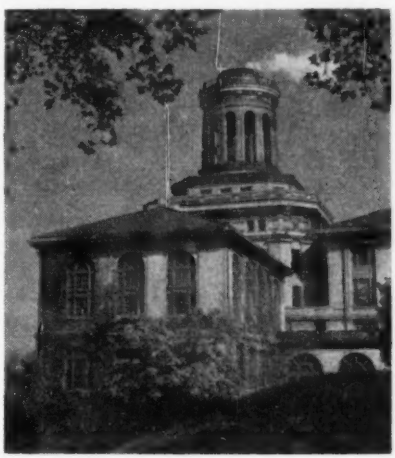
research laboratories which have received international recognition for the excellence of their work. The coal research laboratory conducts investigations on coal and its products, while the petroleum research laboratory investigates the composition of petroleum and compiles fundamental data concerning the entire field of the thermodynamic properties of hydrocarbons and related compounds. A new research project under the sponsorship of the Manufacturers' Chemists Association, will provide readily accessible uniform data on the physical properties of chemical compounds.

The Metals Research Laboratory pursues basic research on the science of metals, directed toward solving problems of scientific and engineering importance.

The Physics Department's two-million dollar Nuclear Research Center has a 450 m. electron-volt synchrocyclotron which contributes to research in fundamental particle physics and high-temperature nuclear physics and chemistry.

Undergraduate education, graduate education and research and creative attainment—all are important—but at Carnegie Institute of Technology these objectives are all incorporated in the Carnegie plan of liberal professional education. And, most important, the Carnegie plan calls for the same kind of teaching for both the technical and the liberal arts aspects of the curriculum. For, while Carnegie Institute of Technology is a world-renowned engineering and technological school, it is unique among great engineering universities—it consists of six other major divisions in addition to the college of engineering and science. These divisions are: the college of fine arts, which includes departments of drama, music, painting and design, sculpture and architecture; the school of printing management; Margaret Morrison Carnegie college for women; the division of humanistic and social studies; the Carnegie library school; and the graduate school of industrial administration.

The importance of these schools in supplying the unique Carnegie qualities of a professional education cannot be underestimated. Carnegie Institute of Technology is the only major school in the world that offers a degree program in graphic arts and was the first to offer a degree in the dramatic arts. The graduate school of industrial administration is the first school of its kind in the United States and offers a two-year graduate program to candidates for the master's degree in that field. The GSIA was founded only seven years ago yet is one of only two business schools in the United States—the other being Harvard University—that has received a Distinguished Research Professorship from the Ford Foundation. Carnegie Institute of Technology—a private co-educational institution, privately financed with a physical plant valued at 20 million dollars and an endowment of 33 millions—has made great strides since its founding in 1900 by



Machinery Hall housing the mechanical and electrical engineering departments, one of the first buildings erected.

Andrew Carnegie, the pioneer steelmaker and philanthropist. In only 57 years it has progressed from giving technical and scientific training and serving the local community to setting the pace in professional education with a national and international reputation.

As well as its emphasis on the social and historical element in engineering courses, Carnegie Institute has made arrangements whereby students may combine full-time education in both engineering and the liberal arts. Many prospective enginering students desire a broader training than can be obtained in a four-year engineering course, but hesitate to take a full-time arts course before going on to an engineering school. By arrangement with certain arts colleges, such students may now take three-year degree courses in arts subjects followed by a two-year course for an engineering degree at Carnegie. This saves at least one year of study and gives them an engineering education with a strong liberal background.

To permit the school to continue as a great seat of learning, knowledge, research and creative attainment Carnegie recently announced a $24,350,000 building and development program which has the endorsement of many of the top industrial and business leaders in the United States. In its development, Carnegie does not intend to deviate from its path of quality. The building and development program is not intended to solve the problem of education in the pure and applied sciences by mere numbers. Carnegie has always realized that mediocrity produced *en masse* cannot fulfill the need for creative, highly competent, and strongly motivated business executives, artists, scientists, engineers and leaders of society. Carnegie Institute of Technology will continue to follow the Carnegie plan as its answer to the problem of professional education.

Donner Hall, a dormitory, constructed mainly of aluminum, for 200 male students.

ASEE ANNUAL MEETING

PITTSBURGH, JUNE 15–19, 1959

THE WISCONSIN COURSE IN TRANSPORT PHENOMENA

WARREN E. STEWART

Assistant Professor Chemical Engineering Department
University of Wisconsin

An address to the Engineering-Physics Joint Session on Heat and Mass Transfer, American Society for Engineering Education Annual Convention, Berkeley, California, June 19, 1958.

As part of a general curriculum revision, the Chemical Engineering Department at the University of Wisconsin has set up a new course in the physics of heat, mass, and momentum transport. The course emphasizes logical mathematical development, and presents the theory of the transport phenomena as a single unified subject. It is hoped that the course description given here, and the text now available in preliminary form,* will help other engineering schools to meet the need for instruction in this vital area.

The need for such a course in our curriculum was clear. Chemical engineering applications necessarily involve the transport phenomena to a large degree, and knowledge in this field is expanding rapidly. Our only required undergraduate instruction in this area was a traditional "Unit Operations" program dealing with the design and operating characteristics of standard process equipment, which failed to show the fundamental unity of the principles involved and did not effectively prepare students for research or further study in this field. To correct this situation, it was decided to shorten the study of unit operations and precede it with a basic course on transport phenomena.

Organization of the Course and Text

The course, *Transport Phenomena*, is intended to provide a broad view of the field in preparation for later specialization.† This calls for a skeleton treatment in which the most fundamental and useful principles, and their interrelations, are stressed. In such a treatment, it is natural to organize the material into a logical sequence on the basis of theory, rather than applications. This organization results in a course that can be taken, with equal benefit, by engineers in different fields.

Table I ‡ illustrates the role of theoretical principles in the organization of the course. First, the subject is divided by *physical nature* into three parts: momentum transfer, heat transfer, and mass transfer or diffusion. In addition, there is a second natural division according to the level of mathematical description, ranging from the detailed description provided by molecular theory to the overall description usually employed in engineering design.

Table I figures prominently in the presentation of the course. It is presented to the students in the initial lecture as a "road map" of the course, and serves as a useful orientation device during the term. Its major value to the student is that it shows how the understanding of each area strengthens, and is strengthened by, an understanding of related areas.

* R. B. Bird, W. E. Stewart, and E. N. Lightfoot, *Notes on Transport Phenomena*, Wiley, New York (1958). (Hereafter referred to as *Notes*.)

† An excellent discussion of the possibilities for graduate and undergraduate instruction in this field is given by R. B. Bird, in a paper contributed to *Recent Advances in the Engineering Sciences*, McGraw-Hill, New York (1958), pp. 155–177.

‡ Adapted from a similar table in the preface of the Notes.

TABLE I

SURVEY OF TOPICS IN TRANSPORT PHENOMENA

Transport Process → / ↓ Level of Description ↓	Part A	Part B	Part C
	Momentum Transport	Energy Transport	Mass Transport
Molecular theory gives expressions for the fluxes of momentum, energy and mass due to molecular motion, in terms of the "transport properties."	Viscosity μ	Thermal Conductivity k	Binary Diffusivity $\mathcal{D}_{AB}$
Application of the laws of conservation of momentum, energy and mass to a microscopic volume element within a fluid gives the "equations of change."	Equation of Motion	Equation of Energy	Equations of Continuity
Solution of the equations of change, with appropriate boundary conditions, gives "profiles" in terms of the transport properties. Partial information is obtainable from the equations by dimensional analysis, or from their time-averaged form for turbulent flows.	Velocity and Pressure Distributions	Temperature Distributions	Concentration Distributions
Radiant energy transport is often significant, but radiant mass and momentum transport are ordinarily negligible.		Planck's Law. Stefan-Boltzmann Law. Radiant energy interchange between surfaces	
Observed or predicted transfer rates across interfaces are usually reported in terms of "transfer coefficients."	Friction Factors, Drag and Lift Coefficients	Heat Transfer Coefficients	Mass Transfer Coefficients
Integration of the equations of change over a macroscopic region gives the macroscopic (or overall) balances.	Overall Momentum Balance	Overall Energy Balance	Overall Material Balances
	Overall Mechanical Energy "Balance" or Engineering Bernoulli Equation		

The route followed by the course and text is down the successive columns of Table I. The three main topics (momentum transport, energy transport, and mass transport) are thus treated consecutively but in analogous fashion. As the course progresses, frequent comparisons are made, and analogies drawn, between topics at the same level in different columns.

The course material is arranged in order of presentation in Table II.*

* From the Table of Contents of the Notes.

The topical arrangement evidently corresponds to that of Table I. It will be noted that the present one-semester, 3-credit course does not cover the entire text; to do so would probably require 5 credits.

Description of Topics

In the following discussion, it will be helpful to bear in mind that the course is taken in the first semester of the junior year. One semester of rigid-body mechanics, and mathematics up through ordinary differential equations, are required background

TABLE II

OUTLINE OF COURSE* AND TEXT†

Part A. Momentum Transport

Chapter
*1. Viscosity and the Mechanism of Momentum Transport
*2. Velocity Distributions in Steady Laminar Flow
*3. The Partial Differential Equations for Isothermal Viscous Flow
4. Velocity Distributions in Unsteady Laminar Flow
5. Velocity Distributions in Steady Turbulent Flow
*6. Friction Factor Correlations for Steady Flow
*7. Macroscopic Balances for Isothermal, Single-Component Systems

Part B. Energy Transport

Chapter
*8. Thermal Conductivity and the Mechanism of Energy Transport
*9. Temperature Distributions in Solids and in Steady Laminar Flow Systems
*10. The Partial Differential Equations for Non-Isothermal Viscous Flow
11. Temperature Distributions in Unsteady Heat Flow
12. Temperature Distributions in Steady Turbulent Flow
*13. Heat Transfer Correlations for Steady Flow
*14. Radiation
*15. Macroscopic Balances for Non-Isothermal Single-Component Systems

Part C. Mass Transport

Chapter
*16. Diffusion and the Mechanisms of Mass Transport
*17. Concentration Distributions in Solids and in Steady Laminar Flow Systems
*18. The Partial Differential Equations for the Flow of Viscous Fluid Mixtures
19. Concentration Distributions in Unsteady-State Diffusion
20. Concentration Distributions in Turbulent Flow
*21. Correlation of Mass Transfer and Related Processes in Steady Flow
*22. Macroscopic Balances for Multicomponent Systems

* Chapters bearing this symbol are included in the present 3-credit undergraduate course.

† R. B. Bird, W. E. Stewart, and E. N. Lightfoot, *Notes on Transport Phenomena*, Wiley, New York (1958).

TABLE II—*Continued*

Appendices

Appendix A. Summary of Vector and Tensor Notation
Appendix B. Separation of Variables Method for Solving Linear Partial Differential Equations

for the course. At present most students take the differential equations course concurrently with *Transport Phenomena.*

Each of three main parts of the course and text begins with the definition of a transport rate (flux), and the corresponding transport property. In their simplest form,* the defining relations are:

$$\tau_{yx} = -\mu \frac{\partial v_x}{\partial y} \tag{1}$$

$$q_y = -k \frac{\partial T}{\partial y} \tag{2}$$

$$j_{Ay} = -\rho \mathcal{D}_{AB} \frac{\partial \omega_A}{\partial y} \tag{3}$$

These equations state that (1) the flux of x-momentum in the y direction by viscous action is proportional to the velocity gradient term $\partial v_x/\partial y$; (2) the heat flux by conduction in the y direction is proportional to the temperature gradient term $\partial T/\partial y$; and (3) the mass flux of component A by diffusion in the y direction in a binary mixture is proportional to the mass fraction gradient term $\partial \omega_A/\partial y$. The proportionality constants are the viscosity μ, the thermal conductivity k, and the product of the density ρ and the binary diffusivity $\mathcal{D}_{AB}$.

Sources of data on the transport properties, typical numerical values and trends, and modern methods of predicting transport properties from molecular theory or principles of corresponding states, are also given in Chapters 1, 8, and 16. Non-Newton-

* *Notes*, Chapters 1, 8, 16. More complete expressions are given later in the Notes.

ian flow, and diffusion in non-ideal solutions, are considered briefly.

Next, in Chapters 2, 9, and 17, the student is given numerous examples and problems illustrating the formulation of differential momentum, energy and mass balances. The resulting differential equations are solved under various boundary conditions to obtain profiles of velocity, pressure, temperature, or composition. The use of the profiles to obtain other information, such as transfer rates at interfaces, is stressed.

The microscopic approach is continued in Chapters 3, 10, and 18 with the presentation of the "equations of change," which are the momentum, energy and mass balances for an arbitrary microscopic element in a continuous ° fluid. These equations may be written as follows † for a one-phase region in a fluid or solid where n chemical components are present:

Equation of Motion:

$$\rho \frac{D\mathbf{v}}{Dt} = -\nabla p - (\nabla \cdot \boldsymbol{\tau}) + \sum_{i=1}^{n} \rho \omega_i \mathbf{F}_i \quad (4)$$

Equation of Energy:

$$\rho \frac{D\hat{U}}{Dt} = -(\nabla \cdot \mathbf{q}) - p(\nabla \cdot \mathbf{v}) - (\boldsymbol{\tau} : \nabla \mathbf{v}) + \sum_{i=1}^{n} (\mathbf{j}_i \cdot \mathbf{F}_i) \quad (5)$$

Equations of Continuity (Material Balances):

$$\rho \frac{D\omega_i}{Dt} = -(\nabla \cdot \mathbf{j}_i) + r_i \quad (6)$$

where

ρ = local fluid density

$\frac{D}{Dt}$ = substantial derivative operator

$$= \frac{\partial}{\partial t} + v_x \frac{\partial}{\partial x} + v_y \frac{\partial}{\partial y} + v_z \frac{\partial}{\partial z}$$

° Real fluids can be treated as continuous, despite their known molecular nature, with satisfactory accuracy as long as the average properties of the molecular population do not change significantly in a distance comparable with the mean free path.

† *Notes*, Chapter 18.

$\mathbf{v}$ = local mass-average velocity vector

$\hat{U}$ = local internal energy per unit mass of the fluid mixture referred to the elements in given standard states

ω_i = local mass fraction of species i in the fluid

∇ = "del" or "nabla" operator

p = local static pressure

$\boldsymbol{\tau}$ = local viscous momentum flux tensor (viscous stress tensor)

$\mathbf{q}$ = local conduction and radiation heat flux vector

$\mathbf{j}_i$ = local diffusion mass flux vector for species i referred to the mass-average velocity $\mathbf{v}$

$\mathbf{F}_i$ = local acceleration acting on i^{th} species, due to gravitational and other fields

r_i = local rate of production of species i by chemical reaction, mass per unit volume per unit time.

Simplified derivations of these equations, and a summary of the vector and tensor notations involved, are given in the *Notes*.

The physical interpretation of the equations of change is quite simple. Equation (4) states that the rate of momentum change for an element of fluid moving with the stream is equal to the sum of the forces due to pressure and viscous stresses on the surface of the element, and the forces due to fields acting throughout the interior. Equation (5) states that the internal energy of an element of fluid moving with the stream changes because of heat flow by conduction and radiation, work done against the surface forces, and work done by the force fields acting on the interior of the element. Equation (6) states that the mass fraction of component i in an element of fluid moving at the mass average velocity $\mathbf{v}$ changes because of diffusion and chemical reactions. Thus the three equations are merely detailed statements of Newton's second law, the law of conservation of energy, and the law of conservation of mass.

The equations of change play a key role in the course. They are used to obtain exact solutions to simple non-flow or laminar flow problems, and to carry out dimensional analyses of more general situations including turbulent flow and geometrically complicated systems. The equations of change are also shown to provide the basis for the Prandtl boundary layer equations and the semi-empirical film and penetration theories, which have been found useful for predicting and correlating the transfer coefficients.

The equations of change are introduced one at a time as needed. Thus, Chapter 3 deals with the equations of continuity and motion for a pure fluid, Chapter 10 adds the energy balance for a pure fluid, and Chapter 18 contains the equations as given above for nonisothermal flow of mixtures. Each of the equations is "verified" by using it to solve simple problems previously worked by differential momentum, energy or mass balances. A few examples of this type illustrate that the equations of change are of general utility, and that there is no further need to set up differential balances for problems involving transport phenomena.

A number of topics related to the equations of change are best treated in vector and tensor notation. Equations thus stated are compact, expressive and permit many insights that would otherwise be difficult to acquire. To ensure that the student gains these insights, the physical meaning of each notation is explained as it is introduced, and an appendix on vector and tensor notations is included in the *Notes*. In addition, most of our students have previously studied vector analysis as a topic in calculus.[8]

The chapters on unsteady-state phenomena and theories of turbulence are not covered in the present course, due to time limitations and the belief that the other topics available (See Table II) are of more general value. Correlations of transfer coefficients for turbulent flow are covered, however, as discussed below.

Chapters 6, 13, and 21 deal with transfer coefficients, their relations to the velocity, temperature and concentration profiles, their functional dependence as predicted by dimensional analysis, and various correlations of empirical or theoretical origin.

Chapter 14 deals with radiation, a phenomenon ordinarily associated only with heat transfer. Emphasis is placed on the development of the basic relations for energy interchange between solid surfaces.

Chapters 7, 15, and 22 are devoted to the overall (macroscopic) balances. Unusually complete statements are given of the overall momentum balance, the Bernoulli equation or overall mechanical energy balance, the overall total energy balance (First Law of Thermodynamics) and the overall material balances. The meanings of these separate but related formulae are clarified by discussing them as integrated forms of the equations of change,[9] and their use is illustrated by a variety of engineering examples.

Development of the Course

The development of the course, *Transport Phenomena*, has been a team effort involving our entire departmental staff, the students in the course, and the publishers. The course was planned by the professorial staff as part of a general curriculum revision, and weekly staff meetings were held during the operation of the course to review its progress and plan the lecture schedule. The production of the 1000-page mimeographed *Notes* was handled by the department civil

[8] See Chapter 13 of the text by G. B. Thomas, Jr., *Calculus and Analytic Geometry*, Addison-Wesley, Cambridge, Massachusetts, 1953.

[9] R. B. Bird, *Chemical Engineering Science*, **6**, 123–131, 1957.

service staff, and a printed edition is being prepared by John Wiley and Sons. Without this cooperative effort, and the inspired leadership of Professor R. B. Bird, the course and text could not possibly have reached their present state of development since the beginning of the text in August, 1957.

Results to Date

In two semesters of operation, *Transport Phenomena* has been taken for credit by about 80 students, the majority being first-semester juniors in chemical engineering. A study of the performance and opinions of this group indicates that the course material is challenging but within the ability of the average junior student. The selection of topics in Table II, for a one-semester three-credit course, resulted from this study.

Our staff arrangements for the course are quite flexible. Six members of our professorial staff * (all whose other duties would permit) have taught the course. The teaching duties were thus distributed to promote free exchange of ideas and to speed the modification of other courses in the light of this new training.

The new course has made it possible to speed up the study of Unit Operations considerably, as shown by the following comparison:

Semester	*Old Curriculum*		*New Curriculum*	
V	Unit Operations	4 cr.	Transport Phenomena	3 cr.
VI	Unit Operations	4 cr.	Unit Operations	5 cr.

The mastery of Unit Operations achieved under the new program is actually superior, since the students have a deeper understanding of the principles involved. In addition the students learn a great deal about subjects not covered in a conventional unit operations program. Similar advantages would be expected from the combination of transport phenomena with other related courses such as heat transfer, fluid mechanics, and diffusional operations.

Our students and staff have found the study of *Transport Phenomena* stimulating and rewarding. Based on our experience to date, it appears that the course effectively does what it was planned to do: *

1. Presents the physics of heat, mass and momentum transfer as a unified subject.

2. Introduces the student to the molecular, microscopic and macroscopic viewpoints in physics and engineering.

3. Utilizes the student's mathematical training to the fullest extent.

4. Shows how the principles of mechanics may be applied to fluid systems.

5. Develops the student's ability to visualize the physical picture in terms of concentration, velocity and temperature profiles.

6. Develops a thorough understanding of the transport properties and the transfer coefficients.

7. Provides the theoretical background for engineering applications of transport phenomena.

8. Provides solid physics background for those who will later take graduate studies.

9. Develops an awareness for the difference between rigorous theory and empiricism.

10. Develops the ability to analyze the contents of handbooks and other references critically.

* R. B. Bird, contribution to *Recent Advances in the Engineering Sciences*, McGraw-Hill, New York, 1958, pp. 155–177.

* Professors R. J. Altpeter, R. B. Bird, E. N. Lightfoot, W. K. Neill, W. E. Stewart, and C. C. Watson.

It is believed that the objectives just stated are consistent with those of most engineering curricula. This belief is strengthened by the knowledge that a large number of departments of chemical and mechanical engineering are actively considering the adoption of such a course. The objectives seem especially appropriate to the increasingly popular *engineering science* curricula, in which technical specialization is deferred to allow stronger basic training in mathematics, physics and chemistry.

Future Plans

It is expected that *Transport Phenomena* will touch off a series of improvements throughout our undergraduate and graduate curricula. The course material has obvious applications in fluid dynamics, heat transfer, diffusional operations, thermodynamics, chemical kinetics and electrochemistry. Our future efforts will be concerned as much with course work in these related areas as with *Transport Phenomena*, which is now fairly well established.

Transport Phenomena will be given this fall at several other universities. The results of these other operations will be of great assistance in further developing the course and text.

A preliminary printed edition of the *Notes* [*] is now available. This edition is a revised and enlarged version of the notes which were used at Wisconsin last year, and is being issued to gather comments and suggestions for the final revision which is about to begin. We hope that the printed notes will be widely read and that the readers will help us, by their comments, to produce a text that meets their needs with maximum effectiveness.

[*] R. B. Bird, W. E. Stewart, and E. N. Lightfoot, *Notes on Transport Phenomena*, published by John Wiley and Sons, 440 Fourth Avenue, New York, N. Y. (1958).

INTERNATIONAL ELECTROTECHNICAL VOCABULARY 2ND EDITION

The newest section of the second edition of the International Electrotechnical Vocabulary (IEC Publication 50), Group 35, Electromechanical Applications, is now available from the American Standards Association.

IEC Publication 50(35) contains about 90 terms and definitions in English and French, together with the equivalent terms in German, Spanish, Italian, Dutch, Polish, and Swedish, for electromechanical applications in the fields of materials handling, automotive industry, agricultural machinery, clocks, signalling devices, and others.

Group 35 is one of 22 groups of the second edition of the vocabulary which is being prepared by the International Electrotechnical Commission (IEC). Eleven of the 22 groups of the new edition are completed and available from the American Standards Association. The first edition of the International Electrotechnical Vocabulary was published in 1938.

American interests in the work of the International Electrotechnical Commission are represented through ASA. IEC Publication 50(35) may be purchased at $2.40 per copy from American Standards Association, Dept. PR23, 70 East 45 Street, New York 17, N. Y.

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Missouri School of Mines and Metallurgy

Teaching Principles of Transfer of Impact Energy

There are many of the fundamental aspects of blasting which are not thoroughly understood. While research into this problem involves a number of complicated problems in physical chemistry, dynamics, electronics, advanced mathematics and impact strength of materials, the teaching of some of the presently known and established principles can and must be taught on the undergraduate level (Fig. 1). Although the complete subject matter discussed here is very complex, simpler types of problems together with the principles in terms of which they are explained can be taught to students on the junior level in engineering in most, if not all, of our mining schools.

General

Perhaps the most significant source of energy applicable to mining processes is found in high explosives (nonnuclear). High explosives exhibit the ability to *detonate* rather than *deflagrate* as does black powder. A deflagration is a rapid burning, while a detonation is characterized by the propagation of a shock wave supported by a chemical reaction (Table I). Explosives which detonate are employed almost exclusively for blasting because the time and manner in which explosive energy is released permits their use in the breakage of rocks of a wide range of physical properties. Energy content of various explosives is given in Table II.

Use of high explosives has resulted in an increase in working capacity by a factor of approximately 3000 in rock excavation as compared with pre-explosive methods. And while recently developed atomic explosives release much larger quantities of concentrated energy and have not been adapted to industrial blasting, modern commer-

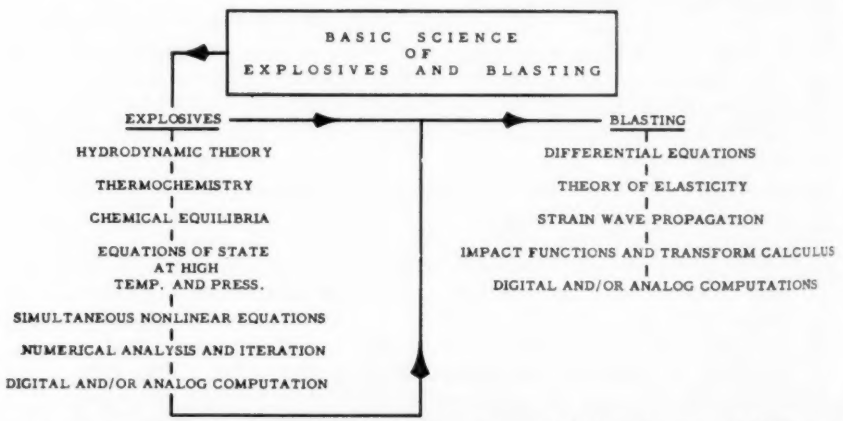

FIG. 1. Flow sheet of basic sciences for teaching theory of high explosives and blasting.

TABLE I[1]

CHARACTERISTICS OF "HIGH" AND "LOW" EXPLOSIVES

Method of Initiation	High		Low
	Primary Ignition	Secondary Detonator	Ignition
Rate of Conversion	Microseconds		Milliseconds
Velocity of Burning Front	One to Five Miles per second		A Few Inches to Feet per Second
Velocity of Flame Front	One to Five Miles per second		One-Third to One Mile/ Second
Pressures of Explosion	Up to 4,000,000 psi		Up to 40,000 psi
Rock Breakage in "Borehole"	3 to 30 tons/pound		3 to 30 tons/pound
Blasting			
Exploded in Gun	Shatters Gun		Good Propellant
Demolition	Excellent to poor		Very poor or nil
Uses	Demolition, Blasting		Propellant, Blasting

[1] Cook, M. A., The Amazing Story of Explosives. *Bulletin* Univ. of Utah, vol. 42, Nov. 7, 1952.

cial high explosives are subject to controlled use and have accomplished as much in raising our standard of living by reducing the cost of producing essential minerals as any other single comparable factor.

While the development of the theories and basic experimentation with high explosives have been largely by the physical chemist, the application of this knowledge to the breakage of rock in blasting processes falls largely in the field of mechanics (dynamics), and more specifically in the field of rock mechanics, a branch of mining engineering science.

Explosives and Shock Waves

The development of the detonation theory is due to Chapman[4] and Jouget.[5] As previously noted, a high explosive is characterized by the property of being able to detonate, which is the propagation of a shock wave accompanied and supported by a chemical reaction in the explosive medium. The difference between a shock wave and a sound wave is indicated schematically in Figure 2, but the difference in pressures, i.e., between p_0 and p_2 is in the order of 10^7 or more.

The distinguishing features of a shock wave are (1) the abrupt or discontinuous rise in pressure, (2) the high pressures attained in the shock wave, and (3) its supersonic velocity. An interesting point concerning shock waves is that both non-reactive and reactive (detonation) waves may be analyzed to a certain degree by the same procedure.

Basically, the relationship of shock wave parameters such as velocity, pressure, streaming velocity, energy and density may be expressed by means of the conservation laws, and this development has become known as the Hydrodynamic Theory. Shock waves may be classed in accordance with the medium in which they occur

[4] Chapman, D. L., *Phil. Mag.*, (5) 47, 90 (1899).

[5] Jouget, E. J., *Compt. rend.*, 1904.

TABLE II

Energy Content:

Atomic Explosives (Rainier)[2]	1,700 tons TNT equiv. $6 \times 6 \times 7$ room
Dynamites[3]	max. 4,000 ft.-lb./gm.
Military Explosives[3]	max. 3,800 ft.-lb./gm.

[2] Johnson, Gerald W., Rainier Blast Opens New Horizons, *E. & M. J.*, April 1958.

[3] Taylor, J., *Detonation in Condensed Explosives*, Oxford, 1952.

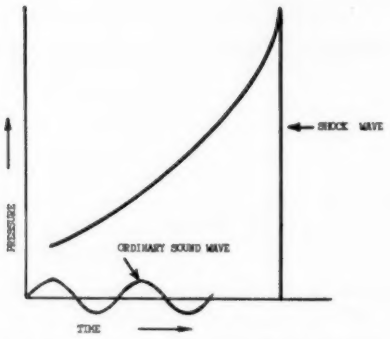

FIG. 2. Time pressure curves for ordinary sound wave and for shock wave.

and whether they are reactive or non-reactive. (See Figure 3.) In *non-reactive* media shock waves quickly decay into sound waves, while in a semi-infinite reactive medium the wave (plane) may continue on indefinitely, once established, without changing any of its parameters. Geometrically, shock waves may occur in either plane, cylindrical or spherical form. The hydrodynamic theory is ordinarily applied, however, only to plane waves.

One way of analyzing the detonation process with respect to blasting is to give credit to the shock wave for the very rapid liberation of a large amount of energy. The propagation of the shock wave, its stability, and efficiency are dependent on a large number of physical and chemical factors.

Additional Physical Laws

The application of the hydrodynamic theory results in certain mathematical relationships between the velocities, density, pressure, and energy in front of and in the detonation wave. Inasmuch as the parameters so defined are insufficient to evaluate the conditions in the detonation wave, additional equations are required. One method of solution (Taylor) prefers the virial equation of state for use in the solution. Cook [6] prefers the use of a modification of Abel's equation of state because it is more tractable to mathematical calculation. The equation is of the form

$$pv = NRT + p\alpha(v) \qquad (1)$$

where α is the covolume, a function of specific volume experimentally determined.

The solution for temperature also adds difficulties to the problem, but it is one of the basic parameters. Hence, the problem becomes one of relating certain of the laws of thermodynamics to the hydrodynamic theory and the chosen equation of state, which also infers that most of the products of the explosion are gases at pressures which may be as high as 200,000 atmospheres and temperatures above 5000° K.

Thermodynamics and Chemistry

An explosion process is assumed to be adiabatic, and the laws of thermodynamics give the following relationship between internal energy, pres-

[6] Cook, M. A., Jl. Chem. Physics, 1947. 15, 518: 1948, 16, 1081.

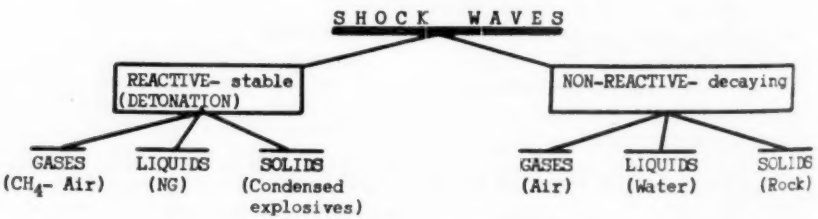

FIG. 3. Shock waves in typical media.

sure and volume:

$$dE = -pdv \qquad (2)$$

From basic material and heat balance equations the heat of detonation is known to be equal to the heat of formation of the products of detonation minus the heat of formation of the explosive. For oxygen balanced explosives, i.e., those which contain enough oxygen to combine with all of the hydrogen and carbon to form water and carbon dioxide, the problem of determining the detonation products is relatively simple. For the more general condition of insufficient oxygen, chemical equilibria must be considered. Equilibrium constants, however, are a function of the unknown temperature of detonation and must be corrected by a fugacity factor. Also, the temperature is dependent upon the heat capacities of the detonation products which are in turn temperature dependent.

This interdependence of parameters suggests that the method of solution will be one of iteration, and this is the case. Temperature maintains such a dominant control of the problem mathematically that this serves as a logical starting point. A temperature is assumed, products calculated, material balance equations satisfied and the resulting temperature checked against the one assumed. This process is repeated until the temperatures agree and then the detonation velocity and pressure are calculated.

Briefly, this and similar methods of calculation may involve the solution of twenty or more non-linear simultaneous algebraic equations, which may be accomplished with some facility on an electric desk calculator. The problem is an ideal one for a digital computer and some portions, if not all of it, can be solved readily upon a properly designed potentiometric analog computer.

One of the remarkable results that the detonation calculations reveal is that the density of the gaseous products of the explosive in the detonation wave is greater than the density of the explosive itself. That is, the greater number of gaseous molecules and atoms are moving in the direction of the burning zone rather than away from it. This condition is compared with quiescent gas and a deflagrating explosive in Figure 4.

Explosion State

With the possible exception of such application as the shaped charge used in a bazooka rocket and oil well casing perforation charges, the detonation wave accomplishes little directly useful work. The explosion state, where the explosion products occupy (instantaneously) the volume occupied by the explosive, is more useful in evaluating effective blasting pressures and temperatures. In mathematical calculations of the explosion state two subiterations are eliminated in solving for the important param-

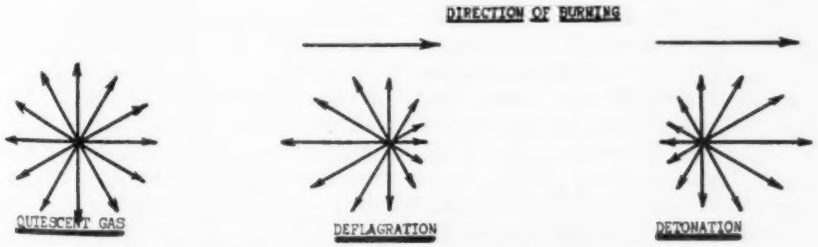

FIG. 4. Three states of average atomic and molecular velocities.

eters of pressure and temperature. From these and the explosion products the ideal available work may also be determined.

Available Work

The expansion of the gases which results from the explosion is assumed to be adiabatic in character and their composition "frozen." Then the available work may be calculated by

$$A = \int_{T_4}^{T_3} p dv \qquad (3)$$

where A is available work, T_3 is the explosion temperature and T_4 is the final temperature after adiabatic expansion. This integral can be evaluated employing Abel's equation of state and other appropriate factors. In many explosives, however, the heat of explosion may be taken as an approximation of the total available energy.

The total energy and the rapidity with which this energy is released have served as fairly reliable criteria in the past for evaluating the blasting efficiency of explosives. The variation of borehole pressure with time and how this affects the explosive's capability to break a given type of rock remains an enigma partly because of problems of instrumentation. For example, no pressure gages have been developed which will withstand detonation pressures long enough to effect a recording of them.

Conditions in Blast Hole

In a blast hole at a given instant during a detonation, the temperatures and pressures generated by the wave and the chemical reaction are higher than those behind the detonation wave. The detonation pressure exists for only a very short time at any position in the explosive column and, hence, does little actual work. The effective work is performed by the explosive gases after they have reached a temporary explosion state at a certain distance behind the detonation wave.

Blasting Action

The transmission of energy from a confined explosive to the surrounding rock is a problem of immediate interest. It is necessary that a free face be present within a certain optimum distance of a confined charge for the rock to break. Thus, for charges located near optimum distances from free faces, the apparently simple question always arose: does the rock break from the inside out or from the outside in?

Reflection Mechanism

Recent research by the Bureau of Mines [7] has shown quite conclusively that in most cases the rock breaks from the outside in, primarily by a slabbing action. As a compressive strain wave generated in the rock by the detonating explosive, impinges upon a free surface at normal incidence, it is reflected as a tensile wave, the magnitude and energy of the reflected wave depending primarily upon the angle of incidence. As the first portion of the wave is reflected, it is superimposed upon the remaining portion, the tensile portion being cancelled until it exceeds the magnitude of the compressive wave. Where the reflected strain exceeds the breaking tensile strain of the rock, it will break. However, part of the strain energy is entrapped in the slab and plays no further part in breaking of rock from the solid. The maximum depth to which a given strain pulse will break is then less than one-half its fall length. Also, of the total spherical strain pulse emanating from a concentrated charge near the optimum dis-

[7] Duvall, W. I., and Atchison, T. C., Rock Breakage by Explosives. Bureau of Mines Report of Inv. 5356.

tance from a free surface only the portion of the energy subtended by a solid angle represented approximately by the crater formed is used in breakage. The remainder is dissipated into the solid rock by direct transmission and reflection. For example, in a 90° solid angle with one free face, less than one-eighth of the total strain energy is used. Hence, single free face blasting represents a very inefficient use of explosive energy. The maximum utilization would occur when the proper amount and type of explosive was placed in a spherical cavity in the center of a free sphere.

Other Mechanisms

There are cases where the reflection mechanism apparently does not apply. In burn cut rounds several drill holes are placed in a closely spaced pattern, usually near the center of a tunnel face, with one or more of the holes left unloaded to provide a cylindrical "free face." In this type of blasting it appears that the pressures and stresses are so intense at this close proximity that the rock between the holes is pulverized and/or sheared as the first compressive wave moves out.

Similitude

The laws of similitude have a very useful application in utilization of explosive energy beyond the equally useful testing of models. Aside from certain non-homogeneous factors which are often negligible, a very simple law of similitude can be applied with ease to rocks of the same type and blasting conditions of the same geometrical configuration. All linear dimensions of a given configuration must vary linearly with each other and the charge size (i.e., linear dimension) must vary in the same manner. A convenient scale factor is usually chosen as $\bar{r} = \sqrt[3]{W}$, where W is the charge weight, and $\bar{r}$ is a scaling factor taken numerically equal to the cube root of a charge weight in pounds and in dimensions of feet. To reduce dimensions to a scaled size, linear dimensions are divided by $\bar{r}$, areas by $\bar{r}^2$ and volumes by $\bar{r}^3$. Strains are unitless, hence do not require scaling. Other quantities will vary according to the units in which they are expressed. It has been found that the law of similitude can be employed with assurance as a guide in changing drill hole sizes and spacings in blasting practice.

UNIVERSITY OF WASHINGTON NUCLEAR CENTER

The University of Washington on July 1, 1958, assumed the responsibility for operating the former General Electric School of Nuclear Engineering at Richland, Washington. This school was started in 1948 and has provided an opportunity for graduate training in the area of nuclear science and engineering to employees of the General Electric Company and to others in the Richland area. The school will be called in the future the University of Washington Center for Graduate Study at Hanford. Dr. Kermit B. Bengtson has been named director of the school. Participating institutions besides the University of Washington are the University of Idaho, Oregon State College, and Washington State College.

Candid Comments

PROFICIENCY OR PANIC?

MILTON ALPERN

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Submitted for YET Paper Contest–1957. (Third prize–Middle Atlantic Section, ASEE)

In the great national effort toward improvement of engineering education, there is seemingly being ignored a basic weakness in our educational methods. I refer to the method of measuring of student performance—the examination.

Too many of the students that enter our engineering schools either take longer than the minimum necessary time to complete their education or simply drop out. This pattern is difficult to correlate with the expected performance for the type of person who chooses engineering as a proposed career. Probing into the basis of this attrition phenomenon, it may be readily suspected that our conventional examinations, though established by usage of many years, are actually faulty measuring tools.

The mission, primarily, of an examination is to measure the acquired comprehension and ability of the student at a certain stage of his education. Further, it should also measure our own proficiency as teachers.

Ask your graduate assistants or your more mature students who are close to both the taking of and the giving of examinations, or even recent alumni, whether the conventional examination accomplishes these purposes. The most common answers will include the equivalent of: "There wasn't enough time . . ." or, "I became rattled and couldn't think . . ." or, "The trick questions stumped me . . . ," etc. Seldom do we hear claims of lack of knowledge. In other words, more usually than not, the students are probably too nervous during examinations to perform normally, or they think they are, which is just as bad. Measurement is probably taken more of panic response than of proficiency.

Haven't you often suspected that the spread of values that you obtain from an examination would be similar to that which would be obtained from medical surveys of various elements of the body's response to a panic situation? Yet the results of such examinations are used as the basic components in the evaluation of student understanding of subject matter. Certainly this is inconsistent with our typical engineering demand for precise measurement.

The grades derived from a conventional examination are probably a measurement of a conglomeration of many things—varying from pure understanding of a subject matter in the emotionally very stable student, to pure panic response in the emotionally unstable student. Most usually a thorough but undefined mixture of the two is measured.

Based upon the results of this measurement, we decide that one student will be a good engineer and that another will not. The situation is particularly poor in the light of the modern demands for qualified engineering graduates which should preclude any failure on our part to recognize true engineering potential in a student.

We probably do fail only too easily and too often with the measuring tools that we have.

Concern over this matter is certainly not a new thing. However, have we, for reasons of bookkeeping expediency, perhaps accepted the conventional concepts of the examination as a measuring tool even while doubting its validity? If so, the current activities toward improvement of engineering education should also include studies and implementation toward a more valid measurement tool than the commonplace examination.

Possible Solutions

If this be criticism then let it at least be constructive criticism. It should be possible to measure acquired proficiency much more validly and yet practically. I respectfully suggest consideration of the following:

The basic error in the conventional examination as a measuring tool is the *time* element which induces a significant psychological factor. Since we wish to determine the student's proficiency in subject matter, it would seem that only in rare cases should we be concerned with *how long* he takes to demonstrate his proficiency to us. It is therefore recommended that examinations be given with essentially *no time limit*. By so doing, it would be possible to remove the panic response and be left with measurement of pure proficiency. There are several practical ways of doing this. Three are outlined here:

1. Establish a large examination room under continual scheduled proctorship of a group of assistants. Class groups could perhaps have specific examination days scheduled for their use. The room would be open to use throughout the day and the student could use it for as long as he wished. Thus, what is now normally considered a one-hour examination could be worked on for as long as the student would desire, up to, say, eight hours. When he hands in his paper, he would submit a measurement of what he *knows*. Nervousness, due to time limitations, will have been removed from the picture.

We would then be measuring proficiency, not panic.

2. If an honor system is in successful operation at the school, examinations would best be given as "take-home exams" with a couple of days allowed for independent work by the student under desired specifications of "open" or "closed-book," etc. When the student turns in his paper, he is reporting only on what he *knows* and the excuse of shortness of time is gone.

We would then be measuring proficiency, not panic.

3. If the details of the above procedures make them impractical, the recommended scheme would be simply to allow very much more time for examinations than are now common. Three hours should be allowed for a current one-hour examination; six for a current three-hour exam, etc.

Measurement would be of proficiency, not of panic.

An interesting valuable by-product of this system is the disappearance of the need for "part credit" for correct method and wrong arithmetic. Our students can be properly and fairly impressed with the fact that an engineering job that is 90 per cent correctly designed may often be a total failure.

It would be splendid for the engineering profession if the wide-spread application of this examination technique served to substantially and properly decrease the current attrition rate. Students' morale would probably climb with the realization that

they are being fairly measured for what they know. Dishonesty would likely decrease sharply with the realization of "fair" examinations. We educators would be closer to a valid evaluation of the basic understanding that our students have acquired and we would be testing them under conditions more akin to those of industry.

The current introspection and re-evaluation that we are undergoing in engineering education should justify investigation and experimentation in this concept.

COLLEGE PHYSICS IS TAUGHT ON COAST-TO-COAST TV NETWORK

The facilities of a major television network have been turned into a three million square mile classroom for a full credit college course in atomic age physics.

Called Continental Classroom, the program is telecast across the country every morning by the owned and affiliate stations of the National Broadcasting Company.

The course is being offered for credit by more than 300 colleges and universities and will cover two semesters of physics review—from a discussion of experimental method to a lecture on inertial guidance systems. It is the first time in the history of television that a full year course in any field of education has been offered to the general public on a nation-wide basis.

Conducted by Dr. Harvey E. White, Professor of Physics at the University of California at Berkeley and consultant to the Atomic Energy Commission, the course started October 6 and will run through June 5, 1959. Occasionally during the class year guest experts, drawn from the ranks of the nation's leading physicists, will conduct special lectures.

During the first semester Continental Classroom will stress those physical principles necessary for an understanding of atomic and nuclear physics: kinematics, light, dynamics, electricity, hydraulics and magnetism. In the second semester emphasis will be on atomic and nuclear physics. Television lectures will be supplemented by tests administered by the colleges, textbook assignments, problem solving and other out-of-class activities.

In the opening session of Continental Classroom Dr. James R. Killian, Jr., Special Assistant to President Eisenhower for Science and Technology, called the show "truly a bold experiment in the nation's interest."

"We need more and better teachers and students of physics in the United States if we are to realize the potential inherent in science," Dr. Killian said as guest on the premiere telecast.

Continental Classroom is sponsored jointly by NBC, The Ford Foundation, the American Association of Colleges for Teacher Education and the Fund for the Advancement of Education.

Participating colleges and universities may utilize the program at no cost and may charge regular tuition fees for those registering for credit. The AACTE recommends that a minimum of three hours of credit be given each semester; however, the amount of credit a college or university offers will be determined locally.

A SOCIAL SCIENCE–HUMANISTIC COURSE WITH A PRACTICAL FOCUS: ENGINEERING ETHICS

RICHARD CONRAD

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> ". . . science [and technology] needs from time to time, as a necessary regulator of its own advance, a labor of reconstitution, and . . . this demands an effort towards unification, . . . involving . . . ever-vaster regions of the world of knowledge."
>
> José Ortega y Gasset

Through a mutual process of challenge and response, demand and supply, call it what you will, engineering has become a significant mediator of change in twentieth century society. Technological advances have been nourished by scientific discoveries and by the progressive perfection of engineering's own skills and techniques. These advances have been eminently suited to the needs of society, which has in turn clamored for more and more. This process has provided a favorable matrix within which engineering both responds to and modifies the social situation. We may say that, in an important sense, society becomes what engineering allows it to become.

Within the profession this protean growth has led to a condition which is paradoxical and threatening. The term "engineer" is now meaningless; the engineer as such, in fact, has disappeared. It is always necessary to ask, "What kind of engineer?" The field has become so vast, and the technical knowledge in each area so great, that the profession has outgrown the scope of individual capacities. The world of the individual engineer has been gradually restricted and confined into ever narrower fields of specialization.

The history of technology shows a twentieth century dilemma: while the engineer has been increasing in social influence, he has had to reduce the sphere of his work in order to enhance his effectiveness, thus progressively losing contact with other sciences and with some of the social outcomes of his specialized work. Professional engineering organizations have stood valiantly against unchecked specialization. They have assumed the role of a professional conscience in regulating engineering education and professional behavior. Engineering organizations recognize the self-destructive dangers which were so eloquently prophesied by Ortega y Gasset in 1930: specialization has approached a stage where it can no longer continue its advance unless it recaptures its relatedness to the larger parts. This course in engineering ethics is predicated on just this premise. The course introduces into professional ethics, a necessary regulator, significant insights into an ever-vaster region of the world of the social sciences and of ethical ideas.

This paper is a report on the "what," "why" and "how" of an elective course in professional ethics for engineering seniors. The course has been developed and taught by a sociologist interested in the study of professions and of social ethics in industrial societies. It was planned in close cooperation with a colleague in the Department of Civil Engineering, Professor Ranald V. Giles, and with

the support of the administration. The senior year in an engineer's training is a propitious period in which to consolidate his learning of major social science principles and of humanistic ideas, conveyed in general education courses, and to view such a practical issue as professional ethics as part of a larger unit.

Engineering ethical practices are essentially judgments. Technical courses prepare engineering students for technical judgments. The course in professional ethics points at the close relationship between technical and non-technical judgments as defined in the codes of engineering societies. But what is equally important, this course relates the prescribed non-technical judgments to the sciences of man in an industrial society and to ethical theories. In short, the *raison d'être* of professional ethics must be grasped intellectually before they can have professional meaning in the life of the future engineer.

What is the Course About?

It was relatively easy for an engineer and a sociologist to produce an academic course in engineering ethics. The former wanted to persuade seniors in engineering to think of themselves as professional engineers and to interact with others in terms of codes established by their societies. The sociologist tried to spread awareness among the next generation of engineers that professional ethics represent a practically sound response by engineers to their place in twentieth century America. As a logical outcome of the two complementary interests, the elective course was entitled, "Engineering Ethics: A Profession's Response to an Industrial Society's Challenge."

This engineering ethics course is about moral judgments (ethics) which affect professional relationships between an engineer and others. Others who are involved in the engineer's interaction include colleagues, other professions, employers, clients and the public at large. We are starting with an immediate issue, the professionalization of engineering, but place this specific issue against a broad background of organized people and of belief systems. In short, it can be shown that ethics of engineering societies are not arbitrary but that they make sense if seen in a social perspective.

This background has at least four discernible dimensions. One of them has to do with major problems of ethical inquiry and with some contemporary ethical solutions. Members of this course explore the ways in which engineering ethics deal with major ethical issues.

Another dimension highlights the increasing impact of the activities of the professional engineer on the social structure of work, education, administrative control and social classes in industrial communities. Industrially-oriented societies such as in the United States have a culturally favorable disposition toward professional engineers. The engineer, often with only partial awareness of his effectiveness, is becoming a significant agent of social change in industrial societies. The role of the engineer and the social impact of his work are widening. The profession responds to the challenge with a set of rules which specify responsibilities of the engineer toward the public, individual clients, employers and other professionals. During the course of instruction the student will discover that engineering ethics help to make the professional engineer a genuinely responsible agent of frequently unanticipated social changes.

A third dimension explores the individual or psychological world and

the sociological world of group relationships and cultural belief patterns of the engineer. His occupational and power position within the economic system of the industrial community is also investigated. Engineering ethics, of course, do not just happen. They are part of sweeping developments in group relations and cultural patterns. Simultaneously, we have to watch the reactions of the principal actor, the engineer, to the developments in his profession. The student will be equipped to make sociological generalizations about his profession and to comprehend such psychological processes as learning and attitude formation in regard to the professionalization of engineering. This will help the student to gauge the sociological adequacy of the ethics of his profession and the potential effectiveness of the ethics on the individual engineer's action level.

Finally, a balance sheet of credits is drawn up. Ethically sanctioned professional behavior by practicing engineers and those social-cultural forces in American society which operate to further professionalization are listed as credits. Impeding individual behavior and social-cultural forces are entered on the balance sheet as debits. The student will discover the undeniable interdependence between professionalization and the pursuit of ethically approved engineering behavior. Such an analysis places engineering ethics in the context of decision-making engineers and of vital social forces and can contribute to guidance of long-term organizational planning of engineering societies in an industrial society.

Why a Course in Engineering Ethics?

Academic courses in institutions of higher learning come and go. Even a cursory look at course catalogues covering a few decades reveals amazing academic appearance and disappearance acts. A wholesale approval or condemnation of the investments in a relatively free market of courses conveniently begs some inconvenient questions. First, does the content of the new course make a potentially significant intellectual contribution to the professional engineer in an industrial society? Or, if one restates the question more precisely, what significant learning does this course stimulate which others would not likely accomplish? Second, suppose I approve of the content of this new course, can I be relatively sure that the content is sound in view of known learning principles?

The potential intellectual significance of this course, entitled, "Engineering Ethics: A Profession's Response to an Industrial Society's Challenge," must be pinpointed. As the title suggests, the senior engineering student faces here course subject matter which involves a thesis. It is a thesis about his own profession. It covers the association of profound social organizational changes with basic scientific and applied engineering changes, the increasing part the profession plays as agent of social change in industrial societies and the development of a professional conscience in the form of engineering ethics. In brief, the engineer's professional activities are made relevant to the wider world of organizational trends and of ethical ideas so that he can locate himself in social space and respond appropriately.

The thesis about professionalization of engineering with its code of ethics is tied to social science theories and data and to some basic ethical problems. While most students will have been exposed during their first college years to humanistic and social science courses, they can review and apply

in this senior elective course knowledge from these fields to the practical professional issue of engineering ethics.

This course recognizes basic principles of learning processes. The meanings of concepts and of social-cultural phenomena which were learned in the humanistic and social science course can now be comprehended within the context of actual professional situations. The senior student of engineering ethics will succeed in supplanting relatively empty concepts (e.g. ethics; industrial revolution; personality; professions; etc.) with professionally meaningful situations which are part of the total industrial situation. The student recognizes the urgency for rules of conduct (ethics) for members (personalities) of engineering (professional) groups. This urgency becomes even more apparent as he locates himself in the modern mass society(resulting, in part, from the industrial revolution) which values (culture) technology and individual freedom and de-emphasizes responsibility (ethics) of the individual.

Several years of teaching engineers have convinced this writer that these students can be stimulated to develop intellectual curiosity. They take to challenging theoretical discussions which are buttressed with adequate data. This course affords students adventures in discovering relationships which had previously appeared to them as disjointed phenomena and in discovering the urgency of further professionalization of engineering with its code of ethics. Ideally, the pay-off will consist of intellectual insights into basic processes of an industrial society. Realistically speaking, the student coming out of this course is prepared to answer professional ethics questions on the licensing examinations. He can also understand the organizational urgency for having codes widely practiced and for the genuine individual and small group resistances to the code of ethics.

How the Course is Conducted

A course in engineering ethics as seen from our educational vantage point taxes the creative imagination of the instructor rather heavily. There are no textbooks available which relate pertinent humanistic-social science knowledge to the behavioral code (ethics) of the engineering profession. This instructor had to rely on his intellectual resources and on the generous suggestions and wide experience of his engineering colleague.

As the elective course developed, the following outline was used.

Part I The Significance of the Kind of Decisions which Engineers Make

Topic 1. Engineers and Decision-Making

Illustrations of Different Types of Decision-Making
Illustrations Showing the Need for Engineering Ethics

Topic 2. Engineering Ethics Interpreted as a Profession's Response to an Industrial Society's Challenge

Major Concepts Operationally Defined
The Meaning of the Challenge–Response Thesis
Illustrations of the Development of Professional Codes

Part II Engineering Ethics as Guides to Professional Decision-Making

Topic 3. The Official Version of Engineering Ethics

- History of the Codes
- Areas of Interpersonal Relationships
- Basic Principles Underlying the Code

Topic 4. Application of Codes to Practical Situations

- Illustrations of Approved Professional Decisions
- Exercises in Decision-Making Problems

Topic 5. A Philosophical Profile of Engineering Ethics

- Technology is to Basic Science as Ethics is to Philosophy
- Engineering Ethics and Philosophical Problems
- Engineering Ethics and Contemporary Philosophical Ethical Systems

Part III The Social Matrix of Engineering Ethics

Topic 6. Only Men are Moral

- Biological and Social Nature of Man
- Man's Guides to Decision-Making are Relative
- Engineering Ethics Attempt to Insure Moral Decisions

Topic 7. The Primary Datum of the Social Sciences is Social Change

- The Nature of Social Change
- Engineering and Social Change
- Industrial Societies and Problems of Change

Topic 8. The Engineer's Organizational Response to Changes in an Industrial Society

- Professionalization of Engineers
- Ethics and Professional Organizations
- In-Going and Out-Going Functions of Engineering Societies

Part IV Balance Sheet of the Effectiveness of Engineering Ethics

Topic 9. Factors Limiting the Effectiveness of Engineering Ethics

- Business Ethics and Engineering Ethics
- Individual Resistances to Engineering Ethics
- Organized Resistances to Engineering Ethics

Topic 10. Engineering Ethics and the Sane Industrial Society

- The Meaning of the Term "Sane" Industrial Society
- The Social Scientific Adequacy of Engineering Ethics
- The Social-Psychological Significance of Professional Ethics for Engineers

The use of actual case studies to project the urgency of a professional code at the beginning of the course lends an atmosphere of reality. Case material is continuously interspersed in the lectures in order to clarify scientific concepts and ethical theories. One-third of the class meetings are set aside for class discussion of the lectures and of the reading of *Ethics for Policy Decisions* by Wayne A. R. Leys. Practical ethical engineering problems with their professionally approved solutions take up a considerable part of the discussions. Yet the student never "loses sight of the role his particular subject [professional ethics] has within the great performance of the tragic-comedy of life. If you cannot—in the long run—tell everyone what you have been doing [and why], your doing has been worthless." (Erwin Schrödinger)

Concluding Remarks

During the last fifty years, industrial societies have undergone profound social changes. Engineers are playing increasingly the role of change-producing agents. This widening role of the contemporary engineer demands of him a high level of technical competence and of social wisdom.

Leaders of engineering societies have responded to the challenges of industrial societies through the process of professionalization. Training requirements are standardized and tested. A code of ethics defines the social responsibilities which are involved in the engineer's work.

The task of professionalization, however, meets culturally induced and socially organized resistances. The engineer who has taken this course can with the help of social scientific insights discover the forces which necessitate and block the professionalization process. He will also reject a moratorium on moral principles and discover in engineering ethics a practical guide for professional decision-making. If successful, this course has brought into the focus of a practical engineering issue, professional ethics, some significant social-scientific and philosophical ideas.

CONSTRUCTION EQUIPMENT DISTRIBUTION CURRICULUM AT CLARKSON TECH

Next year Clarkson College of Technology will offer practical training in marketing earthmoving and roadbuilding machinery and other types of equipment. Dr. William G. Van Note, Clarkson President, announced the establishment of a new curriculum in "Construction Equipment Distribution" starting September, 1959, that will lead to a bachelor of science degree.

Clarkson officials said that the new curriculum has been set up in conjunction with the college's Department of Industrial Distribution, which several years ago pioneered education in that field. In the study of construction equipment distribution for interested students, the college will offer courses revolving around the equipment itself, soils engineering, transportation and public service facilities, construction organization, and, during junior and senior years, courses in civil engineering.

UNDERSTANDING THE ENGINEERING WRITER

P. M. ZALL

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As a sometime technical writer, as a full-time English professor, and as a practising human being, may I submit a protest against the calumny being showered on engineers as writers. Engineers writing reports are no worse than tech writers writing poetry, professors writing sports stories, or men writing women's memoirs. Why pick on engineers?

Of all writers, the engineer is most deserving of respect and sympathy. He is working with materials that defy verbalization, for purposes that deny his intentions, and for readers who at best will be apathetic. Since most report readers read them because they have to (not *want* to), we can hardly expect them to be sympathetic. They ought, however, at least to try to understand what the writer has been up against, what psychological and logical barriers have been overcome.

In the first place, the material of engineering reports is bound to be dull by nature. It is accumulated for purposes of information rather than entertainment. It consists of records, of data accumulated often for its own sake, frequently to prove that the accumulation met a dead end. Yet it represents one step of technological progress, and in record form may prevent many a misstep. The engineer knows this, but still finds it hard to write down the results of a project completed yesterday. Writing gives the information an aura of permanence. He, of all people, knows his work was obsolete as soon as it was completed.

To compound his misery, he runs head-on into critics who insist that he give his writing the life and immediacy of literature or journalism. They insist that there is no real difference between engineering and other kinds of writing, and therefore engineers should write like Hemingway or at least Winchell. But the engineer knows he can not write the suggestive language of Hemingway or the colloquial style of Winchell without being misunderstood.

If he has read much literature, he realizes that its metaphorical content bears the bulk of the meaning; that its style is suggestive rather than demonstrative. The old classic *Humpty Dumpty* is a case in point: Think of it in its standard version, then compare it as it must be presented to a technical audience:

> Humpty Dumpty sat on a wall;
> Humpty Dumpty had a great fall;
> All the king's horses
> And all the king's men
> Couldn't put Humpty together again
> Because he was an egg.

There is the problem. The engineer can not risk leaving himself open to misinterpretation.

The difference between engineering writing and journalism is at least twofold, with respect to presentation as well as audience. A journalist is a slave to a narrow column. For that reason alone, it is wise for him to use short words, short sentences, short paragraphs. He is also a slave to a narrowly-interested audience, and thus must exploit human interest, sometimes political and commercial

interests. In doing so, he may have to sacrifice efficiency and accuracy. An engineering writer patterning his work after that of a journalist runs the risk of professional suicide.

Candid criticism of engineering writing can be very helpful, particularly since there is no universally acceptable standard for guidance. But most of the criticism I have read is derogatory when not misleading. In either case it serves no useful purpose for the man who needs it most. Let us, then, leave the engineer alone. Courage, common sense, and confidence will do him more good than all the sages can.

Courage will come with understanding. In the planning stages of his report, the engineer will realize that writing is chiefly a matter of having something to say. Perhaps without worrying about the apt construction of a single, simple sentence, he will pinpoint what he is really talking about. With a word or two or a symbol, he will name it and define it, analyze and prune it to the parts essential to his purpose. Then he will put those parts into some logical order, indicating links or transitions as he goes. This is a familiar process, putting things in their proper places. Seeing them all fit together will give him courage to work out the detailed parts.

In developing each of the points he has chosen to include, his common sense will tell him when he has said enough or not enough to suit his reader. He should be able to judge what evidence he will need and whether it is sufficient for his purpose. This involves understanding his reader well, but his common sense has the virtue of being *common*. Thus he can imagine what his reader ought to know and how much can be taken for granted.

Furthermore, if given half a chance his common sense will also tell the engineering writer that his reader has to be prepared for what is coming. He will put his information into a structure that will introduce the subject most clearly and easily. He will pace his presentation to give only enough information at a time to insure understanding as well as reading. And he will try every trick in the book to make the information easy to read, easy to grasp, easy to use: headings, indentations, illustrations, appendixes, etc. There are hundreds of books on these subjects from which he can choose alternative skills and models. But none can substitute for the discretion of his common sense.

Only in the final stages of preparation need he worry about the writing as writing. Now, with the confidence born of having something to say and of seeing it take integrated form, the engineer can write with conviction. A little confidence goes a long way to achieving the unity, emphasis, and coherence which is the goal of every report. With it, the engineer dares to test how every part fits in with every other part and how they all contribute to one chief objective. He dares to throw out anything not meeting the test of relevance or of precise statement. He dares also to include amplification when needed, to excise it when unnecessary. In short, he is master enough of his material to be his own best critic.

We do not, however, expect him to be the best critic of his own writing. That is difficult even for the professional writer, who must employ an agent to screen his literary output or editors to screen his technical output. It is enough if the engineer says what he has to say, all that has to be said about it, and in a way that shows he knows what he is talking about. It is the mark of a professional man that he also presents his information in a dignified and formal package of articulated, organized, accurate com-

munication. And if he has taken the trouble to use standard mechanics, including understandable spelling and punctuation, he has demonstrated courtesy. What more can we ask than that he mean what he says and say what he means, with accuracy, brevity, and courtesy?

I have said nothing here about that happy hunting ground, the engineer's language—if by language we mean the words he uses. The reason is simple. My assumption is that left alone, he will have confidence enough to translate simple things into simple words, complex things into words appropriate to his subject, reader, purpose. Gobbledegook, let us remember, was a term coined in politics, not engineering. Engineers are people.

UNITED ENGINEERING TRUSTEES

Andrew Fletcher, President of St. Joseph Lead Company, on October 28 assumed the additional responsibilities of President of United Engineering Trustees, Inc.

United Engineering Trustees, Inc. was incorporated in 1904 for the purpose of advancing the engineering arts and sciences. Its Board is composed of three representatives from each of the five professional societies representing the major branches of engineering—mechanical, civil, electrical, mining, and chemical. Among other activities, the Corporation directs the research programs of the Engineering Foundation, which is financed by a fund of over $2,000,000, and also acts in a fiduciary capacity for a large number of joint activities of the major engineering societies.

United Engineering Trustees, Inc. has purchased the block front between 47th and 48th Streets on the United Nations Plaza for the construction of a 20-story Engineering Center, the cost of which is roughly estimated at $10,000,000. Their present home on West 39th Street will be sold, and the Engineering Societies Library will move into the new Center; there the Library can greatly expand the services that have already made it one of the finest public engineering libraries in the country, if not in the world.

In order to bring the benefits of centralized activities in the new Engineering Center to as widespread a group of engineers as possible, the five societies of United Engineering Trustees have extended invitations to other engineering societies to unite with them in using the new facilities as their headquarters. The new Center will include, in addition to headquarters office space for each group, such facilities as a cafeteria, dining rooms, meeting rooms, and a large memorial hall, suitable for group meetings or for major exhibitions of technical progress.

Mr. Fletcher succeeds Walter J. Barrett of New Jersey Bell Telephone Company who has been President of UET since 1955 and who is also the retiring President of the American Institute of Electrical Engineers.

Other officers elected by UET are: George W. Burpee and Willis F. Thompson, Vice Presidents, Charles B. Molineaux, Treasurer, and Steven W. Marras, Secretary-General Manager.

A COURSE IN THE HISTORY OF ENGINEERING

J. S. DOBROVOLNY

Associate Professor of General Engineering
University of Illinois, Urbana

In 1855, Mr. B. F. Greene, Director at Rensselaer, made a study of methods and programs used in European engineering institutions. In his published report, entitled *The True Idea of a Polytechnic Institute,* Mr. Greene outlined the need of broadening studies in the social sciences and humanities. Down through the years other studies of engineering curricula have reaffirmed this need, the most recent being the so-called Grinter Report of June 15, 1955, prepared for ASEE. This report suggests that about 20 per cent of an accredited curriculum be devoted to studies in the social sciences and humanities.

The past decade has brought forth many new advances in science and engineering. These have put an additional strain on existing engineering curricula to include work in new areas of development. Thus, with these two pressures acting upon the engineering educators, many schools have undertaken a study to re-evaluate some of the conventional course work with the intent of including some of these advances in engineering. Since the engineer has to be first of all technically competent in his particular area of specialization, the time allotted for his social-humanistic course work becomes somewhat restricted.

No doubt most engineers feel that an engineering student should receive some formal course work in the social-humanistic area. The competition for space in the engineering curriculum is so acute, however, that perhaps a re-evaluation of some of the traditional courses in the social-humanistic area is in order to satisfy the needs of the engineering student. The particular area to be discussed here is that of history courses.

If the engineer is to be a true professional, he should be aware of the heritage of his profession. There is no better way to do this than by studying history, but two problems present themselves when we consider taking many of the traditional courses now being offered. One of these is that several courses in history are required before a student can fully appreciate the importance of studying history; the other is that many traditional courses now offered stress the social and political developments and neglect developments in science and engineering. To overcome these contradictions, the engineering student should have available to him a course in the history of engineering.

At the University of Illinois such a course has been offered in its present form since 1953. The course is an elective in most curricula and has met with considerable favor by the students. It is offered at the junior and senior level so that the students can properly understand some of the developments in engineering that are being studied in the advanced undergraduate engineering courses.

Course Content

First let us consider the course content and how it is developed. In addition to the study of engineering developments, those in religion, government, and economics are discussed simultaneously so that an understanding of how they react upon one another can be obtained. The course is

divided into major historical periods and each is studied from the above-mentioned viewpoint. These major time divisions, with some of the subtitles covered, are as follows:

A Typical Outline of Subject Matter Used

I. Discussion of Pre-Historic Era (before 3000 B.C.)
Study of early stone age cultures–significance of climate–early magic and religion–water transportation–utilization of tools–urbanization–domestication of animals–irrigation canals and water reservoirs–discovery of copper –invention of the wheel–early temple construction.

II. Ancient Empires (3000–1200 B.C.)
Study of the cultures in Sumer, Egypt, India, and Crete–development of mathematics–developments in cuneiform script and hieroglyphic script–impact of religion in building of temples and pyramids–production of an agricultural surplus–economic development with extension of trade–use of bronze, wood, and stone–development of surveying–development of calendar –increased urbanization–improved irrigation works.

III. The Iron Age (1200–600 B.C.)
The decline of the ancient empires–the use of iron–decentralization of government–decline of engineering works–evolution of pre-Greek cultures.

IV. The Age of the Greeks (600–200 B.C.)
The rise of the Persians–Xerxes' pontoon bridge–Darius' canal–the Ionic thinkers – Socrates – Plato – Aristotle – Archimedes–Alexander the Great–deductive reasoning–influence of slavery –developments in democratic government–astrology–medicine–mathematics–cultural art–public buildings–harbor construction–extensive trade–Alexandrian scientists–astronomy–basic mechanics.

V. The Roman Influence (509 B.C.–476 A.D.)
Etruscans–strong army–strong central government–roads for good communication–aqueducts and water supply–bridges–Vitruvius–war engines–mining–cumbersome numbering system–coming of Christianity–Pax Romana–natural cement–home heating–Colosseum–Pantheon.

VI. The Middle Ages (400–1200 A.D.)
The Byzantine and Carolingian Empires–Justinian and his engineering works–Arabian scientists–power development by the Arabs–Muslim Empire–Arabian advances in mathematics–developments in paper, textile, pottery, chemistry, and medicine–feudal system in Europe–medieval science–Crusaders.

VII. The Beginning of the Renaissance (1200–1500 A.D.)
Establishment of universities–Albertus Magnus–Friar Roger Bacon– beginning of inductive reasoning–military engineering–influence of religion on science–development of Gothic cathedral–developments in power–gunpowder–increased trade–use of textile industry–impact of printing–chemical technology–Holy Roman Empire–disappearance of slavery.

VIII. The Renaissance (1500–1750 A.D.)
Early scientists, da Vinci, Copernicus, Francis Bacon, Galileo, Torricelli–scientific societies–French road building engineers–patent laws–canals–windmills–water wheels–mining–*De Re Metallica*–need for capital–domestic system–power of the press–colonization–reforms in government–professional status for engineer–increased trade–enclosure acts.

IX. Industrial Revolution in England (1750–1830 A.D.)
Power demands–steam engine–demand for coal and iron–improvements in metallurgy–beginning of factory system–coal tar chemicals–mechanization of industry–machine tool industry –road and canal construction–railroads in England–joint stock compa-

nies–slums–Malthusian theory–Adam Smith–expansion of merchantile system– government legislation–child labor–water rights–increased urbanization–John Smeaton and other engineers.

X. Early American Engineering Contributions (1600–1830 A.D.)
London Company–Plymouth Company –agricultural south–industrial north–early men of science and engineering: Franklin, Washington, Jefferson–Revolutionary War engineering developments–Eli Whitney and mass production–steamboats–early canals–Oliver Evans–Pennsylvania rifle–Yankee ingenuity–slavery–independent spirit–use of textile industry–Louisiana Purchase.

XI. Age of Expansion (1830–1865)
Railroad development–mechanization of agriculture–labor shortage–discovery of electricity–Samuel F. B. Morse and telegraphy–Civil War technology –developments in bridge design–gold in California–scientific agriculture–beginning of engineering education–installment buying–Land Grant Act–standardization–Westinghouse air brake–electro-magnets–electric motors –"Drake's Folly"–sewing machine–Charles Goodyear.

XII. Age of Electricity and Steel (1865–1910)
Development of the telephone–developments in radio–electric lighting–power generation–power distribution –internal combustion engine–automobile development–diesel engine–flying machines–steel production–steel bridge construction–expansion of railroads–Suez Canal–food processing–mining and metallurgy–oil industry–Panic of 1873–corporations–trusts–legislation–international technical exhibitions–labor strikes.

XIII. The Age of Mass Production (1910–Present)
Henry Ford and the moving assembly line–improvements in the automobile–World War I technology–communications–AM and FM–television–commercial air lines–diesel electric locomotives–hydroelectric power–steam turbines–metallurgy–plastics–synthetic materials–World War II technology–atomic power–automation–space.

XIV. Sociological Aspects of Engineering
Factors controlling the economic well-being of a nation, inventions, population, natural resources, economic organization, effect of engineering upon the industrialist–effect upon labor–effect upon the farmer–urbanization–standard of living–wars–government–research–legislation–education–highways–atomic power.

During the course of the semester, appropriate slides are shown covering some of the engineering works of past centuries. Some of the typical works shown are Egyptian architecture, Sumerian irrigation works, Greek architecture, Roman roads and bridges, Roman aqueducts, French roads and canals, British steam engines, early textile machines, and other typical engineering developments. Each student is required to deliver a twenty minute talk upon some phase of engineering history that would normally be discussed in class, such as the contributions to science by the Greeks, or the contributions to engineering by Leonardo da Vinci. This arrangement has proven itself to be very workable since no additional time is allocated for talks because the talks are about typical class discussion material. The three hour-exams and the final examination are made up of essay, discussion-type questions. This again provides a diversion for the student, since most of the exercises he does in his technical subjects are of an objective or problem solution nature.

One of the problems that presents itself in offering a course of this type is that of a suitable text, because the subject matter covered is so broad and diversified. The writer has pre-

pared an outline[1] that serves as a guide to the student in his reading. There are also several paperback books[2] that are used as texts, and outside reading is assigned at the library. In some of the areas, there is considerable book material; for other aspects the material is limited. Much has appeared in current professional, scientific as well as popular magazines along these lines, and this material is also suggested for reading.

The Instructor

In some areas, the question may arise as to who should have the responsibility for teaching such a course; the writer feels that this should be a member of the engineering faculty. Of course, the person who undertakes this task has a considerable amount of self-study and preparation to do before he becomes qualified. The engineering background is essential so that proper emphasis can be placed upon the significant scientific and engineering developments that have occurred in the past and relate them with current engineering practices.

[1] *A General Outline of Engineering History and Western Civilization*, Jerry S. Dobrovolny, Stipes Publishing Co., Champaign, Illinois, 1958.

[2] *What Happened in History*, Gordon Childe, Penguin Books, Ltd., Harmondsworth-Middlesex, England, 1942. *The Anvil of Civilization*, Leonard Cottrell, Mentor Books, New York, 1957. *On Understanding Science*, James B. Conant, Mentor Books, New York, 1951. *Machines That Build America*, Roger Burlingame, Charles Scribner's Sons, New York, 1938.

It would be difficult if not impossible for a non-engineer to explain such developments as the evolution of bridge design or the engineering problems encountered in developing the steam engine in terms familiar to the engineering student. The last decade has produced a considerable number of books covering the information in the aforementioned outline. An engineering staff member preparing himself for teaching a course in the history of engineering would have to read as a start about twenty of the books written covering the subject matter as well as some of the excellent articles appearing in such magazines as the *Scientific American*.

The writer finds that when the students are given the proper background they take a genuine interest in finding out why such names as Darius, Leukippos, Socrates, Plato, Vitruvius, Roger Bacon, da Vinci, and Galileo are famous. Emphasis is placed upon the major historical developments and scientific concepts that have evolved throughout our western way of life, rather than requiring a strict memorization of chronological names, dates, and places. This type of course not only exposes the engineering student to a broad survey of history, but it also develops an understanding of his profession. As a result, many students look with favor upon taking additional work in the social-humanistic area of study so that they can obtain some of the more detailed parts of the subject matter opened up in the History of Engineering.

ASEE ANNUAL MEETING

PITTSBURGH, JUNE 15-19, 1959

TEACHING POSITIONS AVAILABLE

ENGINEERING POSITION OPEN—Ph.D. teaching on college level in English 1959–60. Subjects: Engineering mechanics, fluid mechanics, heat transfer, metallurgy. Salary $6,000–$7,000 plus travel. Apply to Dean, Al-Hikma University of Baghdad, Box 260, Baghdad, Iraq.

INSTRUCTOR OR ASSISTANT PROfessor in Civil Engineering beginning Sept. 1959 to teach basic undergraduate courses. B.S. acceptable for Instructorship; M.S. necessary for Assistant Professorship. Apply to Lt. Col. L. K. Himelright, Head, Dept. of Civil Engineering, The Citadel, Charleston, S. C.

ELECTRICAL ENGINEERING. ACAdemic rank and salary open. Opportunity to join and contribute to the development of a recently formed, growing department. Write R. A. Herring, Jr., Head, Electrical Engineering Department, University of Mississippi, University, Mississippi.

ASSISTANT OR ASSOCIATE PROfessor. Will be responsible for courses in the aeronautics option including aerodynamics and airplane performance. Starting fall term 1959. Industrial experience and master's degree preferred. Department of Mechanical Engineering, Oregon State College, Corvallis, Oregon.

UNIVERSITY OF SASKATCHEWAN, Saskatoon, Canada, invited applications for posts as Assistant or Associate Professor of Mechanical Engineering (minimum salary $6,100 per year) and Instructor of Mechanical Engineering (minimum salary $4,800 per year). One professorship is to be filled by a Mechanical or Metallurgical Engineer with an advanced degree to teach properties of metals and metallography and to direct research in this area. Another Professorship is to be filled by a Mechanical Engineer with an advanced degree and having experience in one of the following fields: (a) thermal power generation, (b) manufacture and production of steam or gas turbines, (c) atomic power generation, or (d) industrial management. He would be expected to teach undergraduate thermodynamics and to teach a graduate class and direct research in his specialty. Two positions as instructors are open, requiring Mechanical Engineering graduates with advanced degrees. Applications, with full particulars, should be sent to Head, Dept. of Mechanical Engineering, University of Saskatchewan, Saskatoon, Sask., Canada.

MECHANICAL ENGINEERING INstructor or assistant professor to teach in the area of machine design and mechanics. M.S. degree desirable but an instructor working towards his advanced degree considered. Salary and rank dependent on experience. Graduate studies and consulting opportunities available and encouraged. Write Joseph Modrey, Head of Department of Mechanical Engineering, Union College, Schenectady, N. Y.

MACHINE DESIGN: ASSISTANT OR Associate Professor in Mechanical Engineering. Newly established department offers opportunity to develop a machine design program. M.S. with some experience preferred. Salary competitive on 9 month basis. Write Department of Mechanical Engineering, Utah State University, Logan, Utah.

ELECTRICAL ENGINEERING – ASsistant or Associate Professor. Master's Degree required, Ph.D. desirable. Rank and salary commensurate with qualifications and experience. Old established Southern University, with expanding School of Engineering. Undergraduate and Graduate teaching, with opportunity for directing graduate and research work for right man. Write to Dean, School of Engineering, University of Virginia, Charlottesville, Virginia.

ASSISTANT OR ASSOCIATE PROfessor of Electrical Engineering. M.S. required, Ph.D. or definite plans for continuing towards the Ph.D. desirable. Excellent opportunity for participation in rapidly expanding graduate program. Apply to: Head, Department of Electrical Engineering; Wayne State University; Detroit 2, Michigan.

ASST. OR ASSOC. PROF. IN MECH. Engrg. Special emphasis on vibrations, stress analysis and dynamics. Must have strong interest and competence in developing laboratories. Master's degree; teaching and industrial experience. Write to S. Brooks Walton, head, Mech. Engrg. Dept., San Jose College, San Jose, Calif.

AERONAUTICAL ENGINEERING: Applications are being received for two permanent positions in the Department of Aeronautical Engineering at the University of Alabama. Applicants for one position should have advanced degrees. The other opening could be filled by a person holding only a Bachelor's degree if he were to show promise of becoming a successful teacher. Opportunities for consulting and research are available; both are encouraged. A person who has earned a Ph.D. within recent years would sense an unusually attractive opportunity to develop a graduate program and teach in his chosen field. Salaries depend on qualifications—up to $9,000 for nine months for a professor. Usual academic tenure regulations apply; the University contributes toward retirement and insurance. Please address inquiries to: Colgan H. Bryan, Head, Department of Aeronautical Engineering, P. O. Box 1461, University, Alabama.

MECHANICAL ENGINEERING DEpartment needs additional staff for Thermodynamics, heat transfer, metallurgy and machine design, M.S., Ph.D. or equivalent required. Interest in research desirable. Rank and salary dependent upon training and experience. Apply, Head, Mechanical Engineering Department, Louisiana State University, Baton Rouge, Louisiana.

POSITIONS AVAILABLE FOR QUALified physicist with Ph.D. and some teaching experience. For further details, write to the Department of Engineering Physics, University of Louisville, Louisville, Kentucky.

ASSOCIATE PROFESSOR OF ELECtrical Engineering—to teach and supervise research in Division of Engineering Research and Development effective September, 1959. Ten month basis. Ph.D. required or essentially completed. Write Head, Department of Electrical Engineering, University of Rhode Island, Kingston, Rhode Island.

CIVIL ENGINEERING STAFF POSItion in Sanitary and Hydraulic area. Open only to engineer with M.S. degree. Teaching and industrial experience desirable but not essential. Apply to W. W. Lorell, Head, Department of Civil Engineering, San Jose State College, San Jose, California.

ELECTRICAL ENGINEERING DEpartment Head. Excellent opportunity available for young teacher with Ph.D. Should have teaching and industrial experience. College located in San Francisco Bay Area, electronics industry research, development and manufacturing center. Academic rank and salary open. Write to N. O. Gunderson, Head, Division of Engineering, San Jose State College, San Jose 14, California.

PROFESSORS OR ASSOCIATES IN Civil, Electrical and Mechanical. Ph.D. required. Eleven months contracts. Resume to Dean Engineering, University of Santa Clara, Santa Clara, California.

TEACHING POSITION: ASSISTANT Professor to teach undergraduate courses in fluid mechanics and related fields. M.S. degree required, teaching or industrial experience desirable. Write to Chairman, Department of Engineering, Fresno State College, Fresno 26, California.

DEFINITION OF ENGINEERING

For several years the Recognition Committee of ECPD has been working on a definition of engineering. At its 26th Annual Meeting ECPD voted "to adopt the tentative definition (as given below) for dissemination." Comments are solicited and should be sent to G. H. O'Sullivan, J. L. White Engineering Corporation, 80 Broad Street, New York 4, New York.

"Engineering is the Profession in which a knowledge of the mathematical and physical sciences gained by study, experience and practice is applied with judgment to develop ways to utilize, economically, the materials and forces of nature for the progressive well-being of mankind."

Explanations

1. Engineering is defined as a profession—thereby grouping it with the other so-called learned groups in the community, such as medicine and law.

2. The idea of knowledge is included in the definition because it is felt that it is knowledge that distinguishes a profession and that it is knowledge which the professional applies in the accomplishment of his objective.

3. The scope of the knowledge peculiar to engineering has been limited to the realms of the mathematical and physical sciences to distinguish from medical or psychological sciences, for example. The physical sciences include such items as chemistry, electronics, strength of materials, biology, geology, etc.

4. Study, experience, and practice are enumerated because these are the items by which an engineer is judged and which he must, in fact, prove if he is to be accepted as a professional by any legal jurisdiction.

5. The idea of judgment is included in the definition in part to comply with the suggestions which a number of critics have offered, namely, that economics is a sufficiently important phase of engineering activity to justify its inclusion specifically in the definition. Whether or not a matter is economical is usually a matter of judgment. In addition, many engineering decisions are made in areas not subject to specific and accurate analysis.

6. The words from "to utilize . . ." are extended to convey, first, that economics is a primary consideration in all engineering, and second, that the engineer's tools are the resources of nature and his aim to improve human welfare. Thus these words cover the objectives of the engineer as well as his mode of operation. The use of materials and forces which are new or not well known is not excluded.

JUNIOR ENGINEERS AT MONTANA STATE

Another Junior Enginers' and Scientists' Summer Institute is scheduled for the Montana State College campus, June 7–20 of 1959, reports James Cusick, faculty coordinator for the event.

JESSI is a two week course designed as an "eye-opener" for high school juniors and seniors. Its purpose is to point out to the students the opportunities and requirements in the fields of engineering and science.

The session is sponsored by the Scientists of Tomorrow organization and MSC. Additional information will be released early in 1959.

ECPD ACCREDITATION

A revised statement on "Additional Criteria" was approved at the 1958 annual meeting of the Engineer's Council for Professional Development. This article gives the original basis for accreditation and then the revised statement, because the two must be together for a complete understanding.

Basis for Accrediting Engineering Curricula

The following statement, proposed by the Committee on Engineering Schools, and approved by Council, October 10, 1933, and by the constituent member organizations, embodies the principles in accordance with which accrediting is conducted.

I. Purpose of accrediting shall be to identify those institutions which offer professional curricula in engineering worthy of recognition as such.

II. Accrediting shall apply only to those curricula which lead to degrees.

III. Both undergraduate and graduate curricula shall be accredited. (Accrediting program at present applies only to curricula leading to first degrees in engineering.)

IV. Curricula in each institution shall be accredited individually. For this purpose, ECPD will recognize the six major curricula—chemical, civil, electrical, mechanical, metallurgical, and mining engineering—represented in its own organization, and such other curricula as are warranted by the educational and professional conditions pertaining to them.

V. Curricula shall be accredited on the basis of both qualitative and quantitative criteria.

VI. Qualitative criteria shall be evaluated through visits of inspection by a committee or committees of qualified individuals representing ECPD.

VII. Quantitative criteria shall be evaluated through data secured from catalogs and other publications, from questionnaires, and by verification by the visiting committee.

VIII. Qualitative criteria shall include the following:

(1) The extent to which the curriculum develops the distinguishing characteristic of the engineer—ability to design, recognized in its broadest sense by the committee to be the "ability to apply creatively scientific principles to design or develop structures, machines, apparatus, or manufacturing processes, or works utilizing them singly or in combination; or to construct or operate the same with full cognizance of their design, and of the limitations of behavior imposed by such design; or to forecast their behavior under specific operating conditions; all as respects an intended function, economics of operation, and safety to life and property." This definition forms part of the committee's statement, "Differentiating Characteristics of an Engineering Curriculum."

(2) Qualifications, experience, intellectual interests, attainments, and professional productivity of members of the faculty.

(3) Standards and quality of instruction:

  (a) In the engineering departments.

  (b) In the scientific and other co-operating departments in which engineering students receive instruction.

(4) Progression of courses and the manner in which fundamental scientific training of the earlier

years is carried into the teaching of the later engineering courses.

(5) Scholastic work of students.

(6) Records of graduates both in graduate study and in practice.

(7) Attitude and policy of administration toward its engineering division and toward teaching, research, and scholarly production.

IX. Quantitative criteria shall include the following:

(1) Auspices, control, and organization of the institution and of the engineering division.

(2) Curricula offered and degrees conferred.

(3) Age of the institution and of the individual curricula.

(4) Basis of and requirements for admission of students.

(5) Number of students enrolled:

(a) In the engineering college or division as a whole.

(b) In the individual curricula.

(6) Graduation requirements.

(7) Teaching staff and teaching loads.

(8) Physical facilities—the educational plant devoted to engineering education.

(9) Finances: investments, expenditures, sources of income.

Additional Criteria (revised October 1958)

To assist in the identification and recognition for accreditational purposes of those curricula mentioned above, Council adopted Additional Criteria on October 14, 1955. These have proved helpful both to ECPD and to the engineering schools. However, experience has shown a tendency toward a rigidity of interpretation by schools much beyond that intended by ECPD. This revision aims to convey the intended meaning more accurately, especially concerning the engineering sciences. It is to be emphasized that *ECPD desires to encourage new developments and experimentation,* as well as to assist those desiring guidance in achieving good and acceptable standards.

The criteria below include statements concerning basic and engineering sciences. Basic sciences include mathematics, physics and chemistry as well as such fields as geology and biology. In basic sciences the objective is the establishment of fundamental knowledge about nature and its phenomena, preferably including quantitative expression.

Engineering sciences have their roots in basic sciences, but carry knowledge further toward applicability. When a basic science proves pertinent to an engineering application, there develops a corresponding engineering science to bridge between the basic science and engineering. Engineering sciences delve into the more practical or engineering-type situations, illuminate these with logical reasoning based upon the fundamental laws and generic principles of basic sciences, and lead into the statement of and methods of solution for problems fundamental in engineering analysis, design, and synthesis. Fuller discussion of basic and engineering sciences and their role in undergraduate engineering education will be found in reports of The American Society for Engineering Education: *

1. An engineering curriculum acceptable to ECPD will normally be characterized by:

a. At least the equivalent of one academic year of basic sciences,

* Particularly: 1. Report of the Committee on the Evaluation of Engineering Education, June 15, 1955; and 2. Report of the Committee on Engineering Sciences, 1958.

about half of which is mathematics beyond trigonometry.

b. At least the equivalent of approximately one year of engineering sciences. These should provide breadth of coverage and should not be limited to those having apparent specific relevance to the major field. Also recognition should be given to the emergence of new engineering sciences. Because of the merging of boundaries between the basic and engineering sciences, greater significance is attached to the depth and breadth of coverage in, and to the total curricula attention to, both of these areas than to the precise division between them.

c. At least the equivalent of approximately one-half of an academic year devoted to engineering analysis, design and engineering systems.

d. Design of the curriculum for an integrated sequential study of the scientific and engineering area, including both theory and the experimental method. Mathematics and basic sciences should be used effectively in the work in engineering analysis, in the study of engineering systems, and in the preparation for creative design.

e. Depending upon the definition of humanistic-social studies, the equivalent of one-half year to one full year as the minimum content, in the area of humanistic-social studies. Of this content, at least one-half year should be selected from such fields as history, economics, government, literature, sociology, philosophy, psychology, or fine arts, and should not include such courses as accounting, industrial management, finance, personnel administration or ROTC.

2. To achieve an integrated and well-rounded undergraduate engineering curriculum meeting the criteria of Section 1 requires at least four full academic years. The pressures on four-year engineering curricula for strengthening the scientific approach to engineering and the social-humanistic content make it necessary that neither inadequate admission requirements nor additional academic objectives be allowed to compromise the standards inherent in these criteria. The engineering student taking an additional program in a field such as business, law, education, and advanced military science, is in effect pursuing two curricula with separate and different professional requirements and objectives. A realistic view recognizes that such dual-purpose programs require more than the normal four academic years. However, reasonable provision may be made for including in the four years of the engineering degree requirements a limited portion of such an additional program. Practical experience indicates that the total of this portion should not exceed the equivalent of one-sixth of one academic year.

3. These criteria have as their object the assurance of an adequate foundation in science, humanities, engineering science, and introduction to engineering method while providing sufficient flexibility in science requirements to accommodate curricula requiring special backgrounds, such as life science or earth science. They also provide substantial flexibility for expression of the institution's own individuality and ideals. They are regarded as a statement of principles to be applied with judgment in each case rather than with arbitrary rigidity. Finally, they are intended to encourage and stimulate but never to restrain the creative and imaginative.

4. In any case in which the Educa-

tion and Accreditation Committee is persuaded that well-considered experimentation in engineering curricula is under way, it shall give sympathetic consideration to departures from the criteria of Section 1 and shall make appropriate recommendations to ECPD.

5. The committee continues to favor broad basic undergraduate programs in engineering which will prepare a student to take advantage of as many different opportunities as possible, and prefers to minimize the number of specially designated curricula to be considered for accreditation. The committee is prepared to examine for approval any curriculum that appears likely to satisfy its criteria for an undergraduate engineering curriculum. Curricula of a vocational or technical institute pattern cannot qualify, nor can curricula of so specialized a pattern as to provide an inadequate base for engineering of a professional level.

34 FELLOWSHIP AWARDS ANNOUNCED BY NATIONAL SCIENCE FOUNDATION

The National Science Foundation has announced the award of 34 fellowships for advanced study and research in the sciences in the Foundation's Regular Postdoctoral Fellowship Program. One of these, to Richard H. Lyon of Minneapolis, is in the field of engineering. Mr. Lyon will study at the University of Manchester in England.

Fellows were selected on the basis of ability as evidenced by letters of recommendation, academic and professional records, and other evidence of attainment. Applications were reviewed by panels of outstanding scientists under arrangements made with the National Academy of Sciences-National Research Council. Final selection of Fellows was made by the National Science Foundation.

The National Science Foundation Postdoctoral Fellows receive, in addition to stipends, allowances for dependents, tuition, and other normal expenses. These awards will enable the recipients to study or carry on their research in 19 institutions of higher learning in the United States and 16 institutions in other countries.

UNION COLLEGE RECEIVES COBALT-60 GIFT

A substantial quantity of Cobalt 60, which will open up new areas of atomic research at Union College, was presented to the College recently by the Schenectady Varnish Company and is now being used in the study of radiation effects upon different kinds of materials.

Officially rated at 1120 curies in strength, the cobalt is a high intensity source of gamma radiation. Originally purchased by the Schenectady Varnish Company from the Brookhaven National Laboratory, the source has been specially licensed by the Atomic Energy Commission for use on the Union College campus. Use of the Cobalt 60 will be shared by both Union College and the Schenectady Varnish Company.

THE PRINCIPLES AND PRACTICES OF COLLEGE RECRUITING

The General Council of ASEE, at its meeting on November 14, 1958, voted to approve this revision of The Principles and Practices of College Recruiting. The approval was based on the General Council having the opportunity to present comments if further modifications are to be made. The Ethics Committee of the Engineers' Council for Professional Development also has given its approval. The revision was accomplished by a joint committee of ASEE's Ethics Committee and of the College Placement Council.

General Principles

It is in the best interests of students, colleges, and employers alike that the selection of careers be made in an objective atmosphere with complete understanding of all the facts.

Therefore, the recruiting of college students for employment by business, industy, government and education should be carried out by the employers, students and college authorities to serve best the following objectives:

1. To promote a wise and responsible choice of a career by the student for his own greatest satisfaction, minimum wasteful turnover and most fruitful long term investment of his talents for himself, for his employer and for society.

2. To strengthen in him a high standard of integrity and a concept of similar standards in the employing organizations of the country.

3. To develop in the student an attitude of personal responsibility for his own career and advancement in it, based on performance.

4. To minimize interference with the educational processes of the college and to encourage completion of the individual's plans for further edution.

Practices and Procedures

Responsibilities of the Employer

1. The employer should contact the Placement Office well in advance regarding desired interview dates, broad categories of employment expected to be available, college degrees, and other pertinent requirements. He should advise promptly any change in his original request or subsequent arrangements with the Placement Office.

2. The employer should provide suitable literature to give students a true and factual picture of the employing organization. This material should be supplied in sufficient quantities and well in advance of the interviewing date.

3. When both the parent organization and subsidiary or affiliated organization conduct interviews in the same college, the respective interviewers should explain clearly their missions and the connections, both to the Placement Office and to the students.

4. Not more than two and preferably only one interviewer representing an employer should appear for each interview schedule. Arrangements for more than two interviewers should be made in advance, and only for reasons considered adequate by the Placement Office.

5. The Placement or other appropriate officer of the college should be advised in advance of any plans for campus visits by the representatives of an employer, including alumni of the college, to acquaint faculty members or students with company employment activities or opportunities. Such representatives should exercise scrupulous

care to avoid undue demands on the time of faculty members or students.

6. An employer who desires to contact an individual student at the time of his interview visit should communicate with the individual well in advance, with a notice to the Placement Office.

7. The interviewer should clearly explain to the Placement Office and students any special requirements such as the passing of tests, physical examinations, signing of patent agreements, or if his job is affected by any union contract.

8. The interviewer should be punctual. He should tell the Placement Office when he will arrive as well as his expected departure time. Every effort should be made to avoid last minute cancellations.

9. The interviewer should very carefully follow the interview time schedule agreed upon with the Placement Office.

10. As soon as possible following an interview, the employer should communicate with the student and the Placement Office concerning the outcome of the interview.

11. The employer should give the student reasonable time to consider his offer, and in no case should the student be pressured into making a decision concerning employment.

12. If the employer invites a student to visit his premises for further discussion of employment, the visit should be arranged to interfere as little as possible with class schedules. He should explain what expenses will be paid, how, and when. Invitations for this purpose should be made only on an individual basis and the employer should avoid elaborate entertaining or overselling.

13. The employer should not offer a student special payments, gifts, bonuses, or other inducements, nor should he compensate or favor a third party to prevail upon the student to accept an employment offer.

14. Employers should not raise offers already made except when such action can be clearly justified as sound industrial relations practice, such as, when an increase in hiring rate is required on an overall basis to reflect salary adjustments in the employing organization.

15. The employer should keep the Placement Office informed concerning his interest in particular students and his negotiations with them.

16. When a student has declined a job offer, the employer should accept that decision as final. If for any reason the employer wishes to re-establish contact with the student, he should do so only through the Placement Office.

17. The employer should engage each student who has accepted his offer except when failure to do so is the direct result of contingencies explained during the interview or unavoidable economic factors not foreseen when the offer was made.

Responsibilities of the College

1. As part of its general obligation for the development of the student, the college should accept responsibility for stimulation of his thinking about his career objectives and for assistance in overcoming handicaps which may hinder his progress toward objectives appropriate for him. Competent counseling services should be provided for this purpose, available to individual students.

2. The Placement Office should inform employers concerning the number of students available for interview in the several curricula, and the dates of graduation. This information should be sent as soon as it is available.

3. The Placement Office should announce to students early in the school year which employers will interview students and when. The Placement

Office should make revised announcements from time to time as may be necessary.

4. The Placement Office should make employment literature available to students and faculty.

5. When an employer is looking for graduates in several fields (e.g., engineering, psychology, physics) the Placement Office should issue announcements to all qualified students concerned, and, so far as practicable, should schedule interviews for those who express interest.

6. The Placement Office should not restrict the number of interviews per student, except as necessary to discourage indiscriminate "shopping."

7. The college should provide adequate space and facilities for quiet and private interviews.

8. The Placement Office should provide interviewers with available records of those students in whom they are interested.

9. The Placement Office should arrange for interviewers to meet faculty members who know students personally and can provide information about their work and qualifications.

10. The Placement officer and faculty members should counsel students but should not unduly influence them in the selection of jobs.

11. The Placement Office should make certain that students are acquainted with this statement of "Principles and Practices of College Recruiting."

Responsibilities of the Student

1. In seeking company interviews, the student should recognize his responsibility to analyze his interests and abilities and consider carefully his career objective and appropriate ways of meeting it. He should read available literature and consult other sources for information about the employer and organize his thoughts in order that he may intelligently ask and answer questions.

2. The student should contact the Placement Office well in advance regarding desired interviews or cancellations.

3. The student should use care in filling out such forms as may be requested in preparation for interviews.

4. In his interviews, the student should recognize that he is representing his college, as well as himself, and should be punctual and thoroughly businesslike in his conduct.

5. The student should promptly acknowledge an invitation to visit an employer's premises. He should accept an invitation only when he is sincerely interested in exploring employment with that employer.

6. When a student is invited to visit an employer's premises at the employer's expense, he should include on his expense report only those costs which pertain to the trip. If he visits several employers on the same trip, costs should be prorated among them.

7. As soon as the student determines that he will not accept an offer, he should immediately notify the employer.

8. The student should not continue to present himself for interviews after he has accepted an employment offer.

9. Acceptance of an employment offer by the student should be made in good faith and with the sincere intention of honoring his employment commitment.

10. The student should keep the Placement Office advised concerning his employment negotiations in accordance with the policy of his Placement Office.

CANDID COMMENTS

FOREIGN LANGUAGES IN THE HUMANITIES PROGRAM

KNIGHT PRYOR

Executive Assistant
Remington Rand Univac
St. Paul, Minnesota

I have just finished re-reading Professor Fred Landis' article, "An Engineering Teacher Looks at the Humanities Program" in the March, 1958, issue of the JOURNAL OF ENGINEERING EDUCATION. I undoubtedly also read the Grinter report referred to, but have forgotten its contents in the space of three years since it appeared.

My interest in this subject might appear on the surface to be remote, since it is ten years since I left the profession of teaching, and at that time I had taught mechanical engineering for only two years. During that employment, however, I spent one of the two years as Chairman of the "Social Humanistics" committee of the engineering school where I taught. We were in the growing pains period of shifting from the four to the five year curriculum, and most of the department heads merely tried to work in more engineering subjects to take care of the fifth year. For example, in mechanical engineering we taught such subjects as "Steam Turbines" and "Air Conditioning," ordinarily reserved for graduate work. This helped to fill out the course, whereas we should have worked in a liberal arts schedule.

I have only one bone to pick with what I have read to date on this subject. As Professor Landis states, any evaluation of present programs must reflect the opinions of the writer. My opinion is possibly biased by the fact that I spent two years of my graduate work at an engineering school in Paris, France. The glaring omission I see from the various humanities programs suggested is the absence of a foreign language.

In the electronics business in which I am now engaged, we have had visits by various technical representatives of foreign countries, such as France, Japan, West Germany, and Latin American countries. Our company has sales offices and/or plants in many countries of the world, covering, I believe, all continents. In practically all cases we expect our foreign contacts to provide English translations or interpreters, rather than vice versa.

Also, there is a wealth of foreign technical knowledge published and available, even in Russian, which remains largely untapped because, though there are people available who may have a knowledge of the language involved, the technical terms remain a mystery. I myself, in an extracurricular activity, have translated numerous technical documents from French to English in the ordinary course of business right here in St. Paul, Minnesota.

Language is the basis of all communication. Much has been said in discussions of the Humanities Program concerning the current inability of many engineers (and others) to express themselves clearly and grammatically. Not the least of the advantages of study in this field, particularly in the Classical and Romance languages, is the resultant broadening of understanding of the grammatical background and immense capability

of expression contained in English itself.

Let me emphasize that I do not necessarily advocate starting from scratch on a foreign language in the engineering school. (A possible exception might be Russian or Japanese, neither of which can be expected in high school curricula.) In my opinion, many high schools are at fault for de-emphasizing the value of a foreign language. Those which serve the colleges should be encouraged in this respect. Also, in my opinion, probably the best our engineering schools can be expected to do at this time is to encourage those students who have taken a foreign language in high school to continue it in engineering school. The final term of the language course should emphasize the technical language of the engineering subjects the student is taking. This was done in my own case at the U. S. Navy Post Graduate School, and it proved invaluable when I was sent to Paris in 1937. The language has stuck with me fairly well, though it is rusty due to infrequent use.

Our company has its existence due to engineering and we hire many graduate engineers. In my opinion their value to the company, if only due to the flexibility of possible assignment, would be greatly enhanced by the ability to speak, read, and write a foreign language. Besides, it is fun.

NEW GRADUATE STUDY PROGRAMS AT MICHIGAN

Two-year programs of graduate study in engineering at The University of Michigan were approved by the Regents. The programs, to be given by the School of Graduate Studies, will require 30 credit hours of work beyond the Master of Science in Engineering level or its equivalent to be taken at the U-M with a grade average of B or better. The new programs will permit a broader subject-area training than is now required for a master's degree.

The programs will include at least 24 hours in the area of the department of program cited in the degree, at least six hours devoted to a research, design or development problem, at least three courses in cognate fields other than mathematics, and at least nine credit hours in mathematics beyond the B.S.E. mathematics requirements of the department cited in the degree.

At the present time, the degrees to be awarded include Aeronautical Engineer, Civil Engineer, Chemical Engineer, Metallurgical Engineer, Electrical Engineer, Industrial Engineer, Mechanical Engineer, Nuclear Engineer, Applied Mechanics Engineer, and Marine Engineer. Additional degrees of this type may be added if the need develops.

While initiating the new degree programs in engineering, the Executive Board requested the discontinuance of professional degree programs in engineering, forestry and wood technology now in existence which required several years of experience in industry before a degree could be granted. Demand for this type of professional degree was reported to be negligible and the Regents approved the request for them to be discontinued.

CANDID COMMENT

REDUCTION OF PHYSICS CONTENT IN THE ENGINEERING PROGRAM?

ELLIOT H. WEINBERG

Professor and Chairman, Department of Physics, School of Engineering, North Dakota State College, Fargo

This note is submitted in partial fulfillment of the requirements that every controversial issue have each of its facets exposed equally in a journal, so that one can discover eventually which of these facets will take on new lustre in the polishing process, and which will crack and crumble. While others are undoubtedly much better qualified to answer Dean Ryder's recent note [1] they may not have found time in this case, so that my response may have to suffice.

Briefly, Dean Ryder has indicated that the correlation between the first quarter of sophomore physics (mechanics) and engineering statics is negligibly small. He has therefore concluded that "this simple experiment confirms the step taken at Michigan State University in the elimination of some of the classical physics training as a pre-requisite to more advanced engineering training." Mechanics is the classical physics specifically eliminated in his article.

As an opening gambit, I should like to ask Dean Ryder if he has tried putting some sophomores into the physics program *after* their statics course, to see if one can then conclude whether statics is necessary for an understanding of physics? In fact, is it not possible that first quarter physics has, for its fundamental objective, something quite different from statics to teach? As I look, for example, at one well accepted text for this level physics,[2] I find eighteen chapters devoted to mechanics, but not one entitled statics! It is true that several pages are devoted to vector addition, and forces are used as illustrative examples; and it is equally true that the concept of torque is introduced first for the equilibrium case. However, as Dean Ryder has carefully pointed out, Michigan State begins at the beginning, assuming no previous knowledge, so that in a day or two their students can be brought up to the same level in regard to vectors and moments.

A logical development along similar lines would lead to the elimination of mathematics from the overcrowded engineering curriculum, for even though the sophomores have probably had a course in calculus they probably can do no better in statics than those without calculus preparation, if only they can be taught what handbook contains the necessary data on centroids.

It must pose an interesting problem to the Michigan State physics department to teach modern physics, including solid state and nuclear physics, to engineering students who have learned their previous physics in courses such as statics and electrical circuits. At this level, a comparison of students with and without sophomore physics would be especially meaningful. Some sympathy must also be extended

[1] J. D. Ryder, "An Experiment in the Reduction of Physics Content." JOURNAL, pp. 118–121, November (1958).

[2] *Physics for Science and Engineering*. Weber, White and Manning, McGraw-Hill (1957).

to the mechanical engineering staff charged with the teaching of thermodynamics, but forbidden to use the concept of energy, since that mechanics course in which energy conservation is discussed no longer is a prerequisite to thermodynamics. And what of modern physics without the prior concepts of linear and angular momentum? Can it be that, in fact, the engineering staff have taken over the job of teaching physics themselves, in each of their engineering courses? In all fairness to Dean Ryder, this might well be less of a calamity than appears at first sight.

At any rate, to an old fashioned physicist like me it is somewhat alarming to know that the course in sophomore physics has for its sole purpose the introduction of cgs and MKS units "to insure adequate scientific broadening of our students," as the Dean says.[3]

Let us leave, now, the qualitative aspects of the problem and turn to Dean Ryder's "quantitative" results. We are asked here to note that in a group of 77 students, only nine received a grade in statics that did not lie within one letter grade of their grades in physics. The Dean concludes that no conclusion can be drawn. Let us see what his chart (Table I) can tell us.

Of those who received 'A' in physics, only two dropped down to a 'C' while of course there was only one way to go. For those getting 'B' in physics, almost half received an 'A' in statics, which would imply that their background in physics served them well. For those receiving 'C' in physics, almost half did better in statics, while a negligible number fared more poorly. Even for the 'D' physics group more than half did better in statics. As for the 'F' group, the physics department certified these students' ignorance in that field, and the engineering staff evidently wasn't able to teach them anything either.

It is far from the case of "grade begets grade." If one throws out differences of one letter grade, either plus or minus, why not two or three and do away with grades entirely? Can it be that the reason for disregarding differences of one letter grade is that the pluses are far in excess of the minuses?

Turning now to Table II we can see some rather interesting features, if we only wish to look. For example, are we concerned with our better students? Then note that 50 per cent more students with physics than without got an 'A' in statics. It is true that more students with physics got 'D' than those without. But the reason is clear—there were fewer 'D's in statics for those who didn't have physics previously, because they got 'F' instead. The proof is simple. The total number of 'D's plus 'F' is about the same for both groups. It does seem possible that if more than 50 per cent more students got 'A' and about 50 per cent less got 'F' as a result of their physics background, some attention ought to be given to this fact.

While it is certainly not within the province of a physicist to question the advisability of eliminating physics as a prerequisite to more advanced engineering work, I hope that this note will not arrive too late to help others who must make similiar administrative decisions in the near future. If it is true, as Dean Ryder avers, that the physics of yesterday has become the engineering of today, I am very loath to accept the additional premise that the *physicist* of yesterday has become the *engineer* of today. It would rather appear that the engineer of today is being prepared for the job of technician of tomorrow! "O tempora! O mores!"

[3] Ryder, p. 121.

Abstract of the

MINUTES OF THE MEETING OF THE EXECUTIVE BOARD AND GENERAL COUNCIL, NOVEMBER 13 AND 14

W. LEIGHTON COLLINS

Secretary, ASEE

Copies of the complete minutes can be obtained from the office of the Secretary on request.

Two major actions featured the meetings. The first was the approval of the project for a seven-man team to go to India to make a feasibility study for the establishment of an institute of technology at Kanpur, India. Because the group was to be in India within two months of the initial contact, everything was done by telephone with the Secretary and President acting in accordance with the directives of the Executive Board. The request came from the International Cooperation Administration. The contract was signed on November 3 and the group was in India on December 1. Six weeks to two months is to be spent in India. If the report then prepared is acceptable to the Government of India, a more detailed report giving size, space, laboratories, equipment, etc. is to be developed after returning to the United States.

The second major action was the acceptance of the request of the Engineers' Council for Professional Development that ASEE make an evaluation study of technical institute education similar to the study of engineering education they requested several years ago and which led to the "Report On Evaluation of Engineering Education." The Technical Institute Division heartily endorsed the action. An appropriate committee will be appointed to plan the work, seek financing, and carry out the study. It is believed that this is a logical follow-up to the National Survey of Technical Institute Education which just has been concluded.

The Technical Institute Division reported that the English Speaking Union has requested it to participate in the exchange of two representative teachers with the United Kingdom, and requested approval as an ASEE Project. There is no financial obligation to ASEE. Approval was granted. The General Council also VOTED to endorse in principle a technical institute education exchange mission with the USSR.

In order to coordinate the efforts of division editors and to give the Editor of the JOURNAL an advisory group with whom he can consult regarding acceptance of papers for publication, if he believes it desirable, an editorial committee made up of the editors of divisions and other appropriate groups was authorized. The President also was authorized to appoint committees to organize groups and plan programs for the annual meetings for those interested in engineering science curricula and in dean of mens' activities.

The much discussed question of research in the teaching of engineers was again considered. The Research Administration Committee of ECRC took the bull by the horns and agreed

to serve as catalyst to get ECRC, ECAC, the Educational Methods Division, the Graduate Division, and CDEF together to develop a program. On the recommendation of ECRC, the Executive Board allocated $1,500 for travel expenses to the project, the full amount to be repaid when a project is financed. A target date of June 1960 was set for the presentation of an appropriate research program.

The relations with the Federal Government were discussed from a number of points of view. A letter to Dr. L. G. Derthick, Commissioner of Education, was authorized in order to present names of engineering educators to him for consideration for appointment to the advisory committee on fellowships, as authorized by the National Defense Education Act for 1958. The Small Business Bureau of the Department of Commerce wishes to publish as one of its circulars, and at no cost to the Society, ECRC's report "Research Relations Between Engineering Educational Institutions and Industrial Organizations." From 25,000 to 100,000 copies will be sold in the usual manner of the SBA. If the Publications Committee approved (it did), the offer was to be accepted. A summary of the report will be in a spring issue of the JOURNAL. A resolution approved by ECRC voicing objection to the Bureau of the Budget's method for calculation of overhead also was approved by the General Council. The National Federation of College and University Business Officers objected on a cost accounting basis, but ECRC also objects on the basis of the inseparability of instruction and research. In brief, the Bureau of the Budget insists that space and equipment included be exclusively for research. The resolution is to be transmitted to the Bureau of the Budget through the established channel, the American Council on Education.

The revision of Recruiting Practices and Procedures submitted by the Ethics Committee was approved. The new title is "The Principles and Practices of College Recruiting." The revision was drafted by a joint committee of the College Placement Council and the Ethics Committee. ECPD's Ethics Committee has approved the draft, and it is now being submitted to the various placement associations for approval. ASEE's two major contentions regarding previous "codes" of other bodies were recognized and essentially incorporated in the revision; there thus now will be only one "code" in the future. It is expected that the revision will be published in a spring issue of the JOURNAL as well as becoming available as a separate publication.

YET activities also were prominently discussed. $50.00 was allocated to CYET for an experimental issue of a newsletter. It is to be distributed through the Section Representatives. The summer employment program whereby the names and interests of YETs desiring summer employment are tabulated and the lists sold to employers, industrial members of ASEE, was approved for this year, thus rescinding the action of the Executive Board taken at its June, 1958 meeting. A report, including its effectiveness, is to be submitted in June. A committee to make a study of all aspects of employment program needs of ASEE also was authorized.

The Engineering Economy Division submitted a request to the Executive Board to solicit foundation support for the publication of the *Engineering Economist* for a period of three years in order to get it in a sound financial position. The Executive Board expressed interest and concern, but referred the request to the Publications Committee for a recommendation.

Membership activities in all categories are actively getting underway. New individual members are being

added at the same rate as a year ago, but the big push for a successful year is yet to come. Valparaiso and Southwestern Louisiana Universities were admitted to active membership, participating in ECAC. Participation in ECRC has been granted to the University of Houston, University of Cincinnati, New Mexico College of A. and M. Arts, and Colorado School of Mines.

Vice Presidents Eckel and Van Houten have undertaken experimental programs to interest "pre-engineering" colleges in affiliate membership. These efforts will be watched with interest. The Industrial Membership Committee will get its ambitious program underway in December, using a newly designed brochure and an individually typed letter from the chairman of the committee. Individual members of the committee will then follow up.

Life membership was approved for the following fourteen members: O. C. Ayers, Grover Blalock, A. I. Brown, P. S. Donnell, H. C. T. Eggers, C. J. Kiernan, R. G. Paddock, O. W. Potter, G. H. Sechrist, J. T. Tykociner, W. C. Voss, P. A. Willis, Carl Wischmeyer, and J. C. Wooley.

NEW NUCLEAR LAB AT STANFORD

A Stanford University laboratory famous for pioneering in electric power technology now has turned to nuclear power. The Harris J. Ryan Laboratory, a campus landmark since 1926, will be remodeled to serve the University's growing classes of nuclear engineering students.

Stanford trustees have appropriated $87,500 to provide 3,200 square feet of instructional, laboratory, and locker space inside the huge building and for painting and landscaping to improve the exterior.

Upon completion next spring the nuclear power teaching facility should rank among the best of its kind, according to Stanford Professor George Leppert, director of the program and a member of the Mechanical Engineering faculty.

The laboratory's most spectacular item will be a 10-kilowatt teaching reactor soon to be under construction. A "pool" type, it will be financed by a $150,000 grant from the Atomic Energy Commission. Another $25,000 has been given by the C. F. Braun Trust of Alhambra for housing the reactor and its related facilities. The reactor will complement the laboratory's subcritical nuclear assembly, a similar device powered by $80,000 worth of AEC-loaned uranium, which is already in use.

Other facilities will include a radiochemistry instruction laboratory, a radioactivity counter room, a reactor heat transfer research laboratory, and a machine shop and faculty offices.

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